# Smolt Production, Adult Harvest, and Spawning Escapement of Coho Salmon from Nakwasina River in Southeast Alaska, 2004–2006

by

Troy Tydingco

# Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

**Weights and measures (metric)**

| | |
|---|---|
| centimeter | cm |
| deciliter | dL |
| gram | g |
| hectare | ha |
| kilogram | kg |
| kilometer | km |
| liter | L |
| meter | m |
| milliliter | mL |
| millimeter | mm |

**Weights and measures (English)**

| | |
|---|---|
| cubic feet per second | $ft^3/s$ |
| foot | ft |
| gallon | gal |
| inch | in |
| mile | mi |
| nautical mile | nmi |
| ounce | oz |
| pound | lb |
| quart | qt |
| yard | yd |

**Time and temperature**

| | |
|---|---|
| day | d |
| degrees Celsius | °C |
| degrees Fahrenheit | °F |
| degrees kelvin | K |
| hour | h |
| minute | min |
| second | s |

**Physics and chemistry**

| | |
|---|---|
| all atomic symbols | |
| alternating current | AC |
| ampere | A |
| calorie | cal |
| direct current | DC |
| hertz | Hz |
| horsepower | hp |
| hydrogen ion activity (negative log of) | pH |
| parts per million | ppm |
| parts per thousand | ppt, ‰ |
| volts | V |
| watts | W |

**General**

| | |
|---|---|
| Alaska Department of Fish and Game | ADF&G |
| Alaska Administrative Code | AAC |
| all commonly accepted abbreviations | e.g., Mr., Mrs., AM, PM, etc. |
| all commonly accepted professional titles | e.g., Dr., Ph.D., R.N., etc. |
| at | @ |
| compass directions: | |
|    east | E |
|    north | N |
|    south | S |
|    west | W |
| copyright | © |
| corporate suffixes: | |
|    Company | Co. |
|    Corporation | Corp. |
|    Incorporated | Inc. |
|    Limited | Ltd. |
| District of Columbia | D.C. |
| et alii (and others) | et al. |
| et cetera (and so forth) | etc. |
| exempli gratia (for example) | e.g. |
| Federal Information Code | FIC |
| id est (that is) | i.e. |
| latitude or longitude | lat. or long. |
| monetary symbols (U.S.) | $, ¢ |
| months (tables and figures): first three letters | Jan,...,Dec |
| registered trademark | ® |
| trademark | ™ |
| United States (adjective) | U.S. |
| United States of America (noun) | USA |
| U.S.C. | United States Code |
| U.S. state | use two-letter abbreviations (e.g., AK, WA) |

**Measures (fisheries)**

| | |
|---|---|
| fork length | FL |
| mideye to fork | MEF |
| mideye to tail fork | METF |
| standard length | SL |
| total length | TL |

**Mathematics, statistics**

*all standard mathematical signs, symbols and abbreviations*

| | |
|---|---|
| alternate hypothesis | $H_A$ |
| base of natural logarithm | $e$ |
| catch per unit effort | CPUE |
| coefficient of variation | CV |
| common test statistics | $(F, t, \chi^2, etc.)$ |
| confidence interval | CI |
| correlation coefficient (multiple) | R |
| correlation coefficient (simple) | r |
| covariance | cov |
| degree (angular) | ° |
| degrees of freedom | df |
| expected value | $E$ |
| greater than | > |
| greater than or equal to | ≥ |
| harvest per unit effort | HPUE |
| less than | < |
| less than or equal to | ≤ |
| logarithm (natural) | ln |
| logarithm (base 10) | log |
| logarithm (specify base) | $log_2$, etc. |
| minute (angular) | ' |
| not significant | NS |
| null hypothesis | $H_O$ |
| percent | % |
| probability | P |
| probability of a type I error (rejection of the null hypothesis when true) | α |
| probability of a type II error (acceptance of the null hypothesis when false) | β |
| second (angular) | " |
| standard deviation | SD |
| standard error | SE |
| variance | |
|    population | Var |
|    sample | var |

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## SMOLT PRODUCTION, ADULT HARVEST, AND SPAWNING ESCAPEMENT OF COHO SALMON FROM NAKWASINA RIVER IN SOUTHEAST ALASKA, 2004–2006

by

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# ABSTRACT

In 2004, 2005, and 2006, a continuing coded wire tag (CWT) project for coho salmon *Oncorhynchus kisutch* in Nakwasina River near Sitka, Alaska was conducted to supplement a regionwide effort to assess the status of key coho salmon stocks in Southeast Alaska. During spring 2004, 9,771 coho salmon smolt ≥70 mm FL were captured in minnow traps, marked with an adipose finclip, given a CWT, and released. During spring 2005, 12,989 coho salmon smolt ≥65 mm FL were captured in minnow traps, marked with an adipose finclip, given a CWT, and released. The Chapman modification to the Petersen model was used to estimate smolt abundances at 47,573 in 2004 and 64,164 in 2005. Beach seines, gillnets, and hook and line gear were used to capture immigrant coho salmon during autumn 2005 and 2006. Using Jolly-Seber open population models, the estimated escapements were 3,539 in 2005 and 5,698 in 2006. The peak foot survey counts of 892 in 2005 and 996 in 2006 represented 25.2% and 17.5% of the total estimated escapements. The resulting expansion factors in 2005 and 2006 were 4.0 and 5.7, respectively. Estimated harvests of returning Nakwasina River coho in 2005 and 2006 were 1,801 and 1,416, exploitation rates were 33.7% and 19.8%, and marine survival rates were 11.2% and 11.1%. Estimated total runs (escapement plus harvest) for coho bound for Nakwasina River in 2005 and 2006 were 5,340 and 7,114.

Key words: coho salmon, *Oncorhynchus kisutch*, Nakwasina River, harvest, troll fishery, sport fishery, migratory timing, return, exploitation rate, Jolly-Seber, marine survival, coded wire tag, mark–recapture experiment, spawning escapement, smolt abundance, Southeast Alaska, expansion factor.

# INTRODUCTION

Coho salmon *Oncorhynchus kisutch* produced by Nakwasina River and thousands of other coastal river systems in Southeast Alaska collectively support the region's mixed stock commercial troll and net fisheries, and freshwater and marine sport fisheries. The Alaska Department of Fish and Game (ADF&G) has conducted comprehensive coded wire tag (CWT) assessment projects on a long-term basis to evaluate the effects of Southeast Alaska fisheries on specific coho stocks native to streams in northern and inside areas of Southeast Alaska (Yanusz et al. 1999), but stock-specific information is more limited for outside, central, and southern areas. To bridge geographic areas, projects have been implemented more recently for specific stocks, including the Unuk River in southern Southeast (Jones III et al. 1999, 2001; Weller et al. 2002-2003, 2006), Slippery Creek in central Southeast (Beers 1999, 2003), and Chuck Creek (McCurdy 2006) in southern Southeast outside waters. Along the outer coast, the first comprehensive CWT program began at Ford Arm in 1982 and has continued through 2006 (Shaul and Crabtree 1998; Leon Shaul, personal communication, Alaska Department of Fish and Game, Commercial Fisheries Division, Douglas). The Division of Sport Fish also conducted a CWT project to assess fishery impacts to Salmon Lake (near Sitka) coho salmon from 1983 to 1990 and again in 1994–1995 (Schmidt 1996), and 2001–2005 (Tydingco et al. 2006, 2008).

Beginning in 1998 and continuing through 2007, the Division of Sport Fish has conducted a coho salmon CWT project in Nakwasina River (Figure 1) to supplement the regionwide effort to assess the status of key coho salmon stocks in central Southeast Alaska (Brookover et al. 1999, 2000, 2003; Tydingco 2003, 2005a-b, 2006). Estimated smolt abundance in Nakwasina River from 1998 through 2003 ranged from 22,472 (SE = 1,660) in 2002 to 102,794 (SE = 15,255) in 1998. Estimated harvests of returning adults in 1999–2004 ranged from 604 fish (SE = 109) in 2003 to 1,983 (SE = 354) in 1999 (Table 1).

The objectives of this study were to: (1) estimate the number of coho salmon smolt leaving Nakwasina River in 2004 and 2005; (2) estimate the marine harvests of coho salmon from Nakwasina River stocks in 2005 and 2006 via recovery of CWTs applied in 2004 and 2005; and (3) estimate spawning escapements in 2005 and 2006. As a means to develop a cost-effective way to estimate escapement using foot surveys, an additional task of this project was to define the relationship between the estimated escapements and peak foot survey counts.
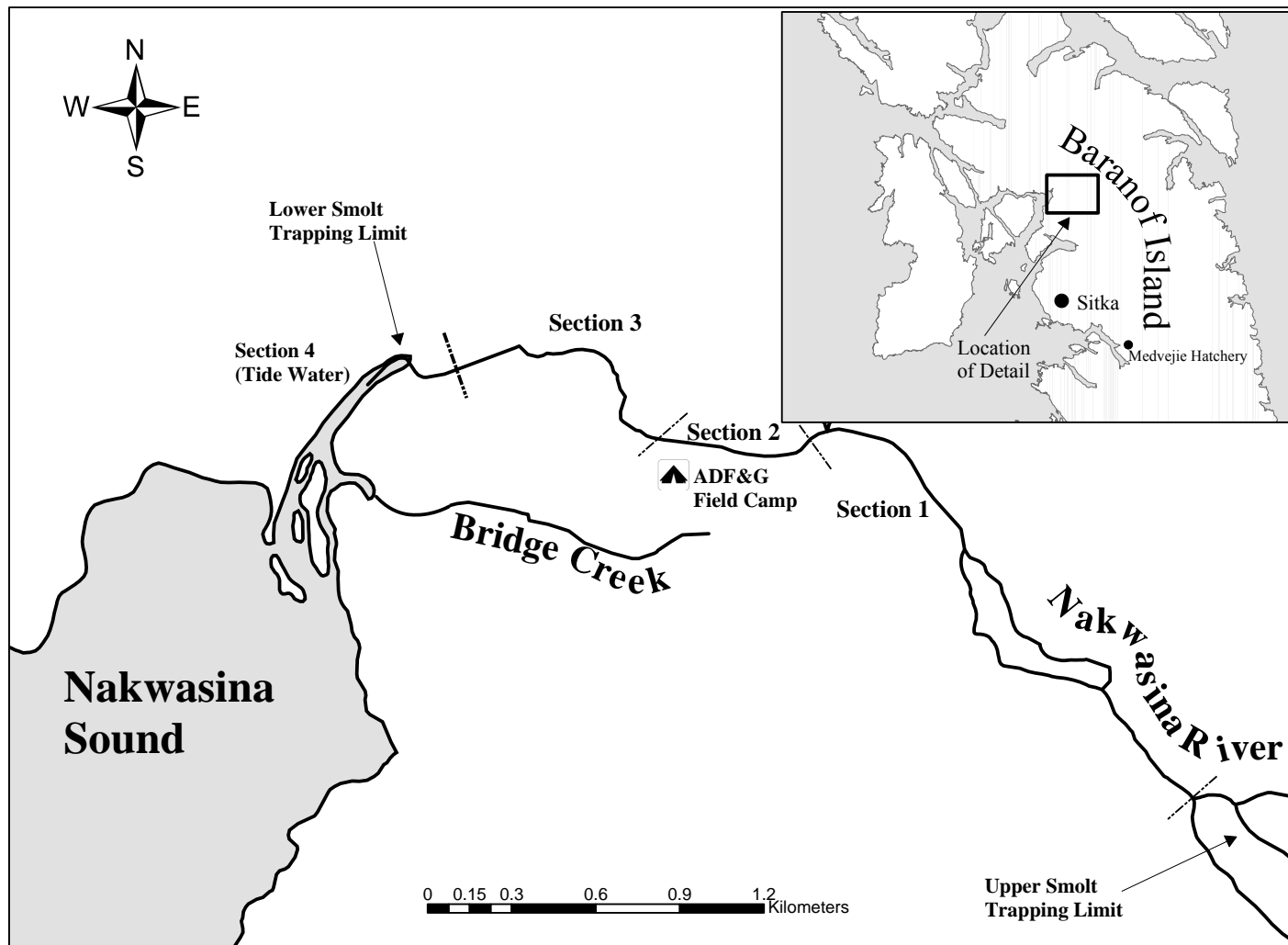
Figure 1.–Map showing Nakwasina River area, including major tributaries and location of ADF&G research sites and stream sections.

Table 1.–Numbers of smolt tagged, smolt abundance with resultant escapement, and harvest from the Nakwasina River 1998–2006.

| Year | Smolt tagged | Smolt Abundance Estimate | Smolt SE | Adult Esc | Adult Esc SE | Harvest | Harvest SE | Survival | Exploitation | Theta | Stream survey peak count | Proportion of escapement estimate |
|------|-------------|--------------------------|----------|-----------|--------------|---------|------------|----------|--------------|-------|--------------------------|-----------------------------------|
| 1998 | 9,980 | 102,794 | 15,255 | - | - | - | - | - | - | - | 653 | - |
| 1999 | 3,971 | 47,571 | 6,402 | - | - | 1,983 | 354 | - | - | 0.095 | 291 | - |
| 2000 | 10,120 | 45,677 | 2,669 | 2,000 | 261 | 1,219 | 213 | 6.80% | 0.379 | 0.082 | 419 | 0.21 |
| 2001 | 10,381 | 43,630 | 2,660 | 2,992 | 510 | 1,439 | 155 | 9.70% | 0.325 | 0.221 | 753 | 0.25 |
| 2002 | 5,686 | 22,472 | 1,660 | 3,141 | 661 | 731 | 109 | 9.80% | 0.178 | 0.237 | 713 | 0.23 |
| 2003 | 15,762 | 55,424 | 4,023 | 2,063 | 233 | 604 | 109 | 11.90% | 0.226 | 0.225 | 440 | 0.21 |
| 2004 | 9,771 | 47,573 | 3,039 | 3,867 | 937 | 1,645 | 178 | 9.90% | 0.298 | 0.286 | 399 | 0.10 |
| 2005 | 12,989 | 64,164 | 3,105 | 3,539 | 817 | 1,801 | 226 | 11.20% | 0.337 | 0.205 | 892 | 0.25 |
| 2006 | 10,644 | - | - | 5,698 | 749 | 1,416 | 167 | 11.10% | 0.198 | 0.202 | 996 | 0.17 |
| Averages | 9,923 | 53,663 | 4,852 | 3,329 | 595 | 1,355 | 189 | 10.06% | 0.277 | 0.194 | 617 | 0.20 |

# STUDY AREA

Nakwasina River is located on the outer coast of Baranof Island in Southeast Alaska (Figure 1). It is about 13 km long, and the anadromous portion ranges between 6 and 30 m wide, and up to 3 m deep. It empties into Nakwasina Sound (57° 15'16.8"W/135° 20'41.5"N) about 23 km north of Sitka. Nakwasina River drains approximately 8,600 ha$^2$ and is one of the larger river systems on Baranof Island. Average daily flow rates between 1976 and 1982 ranged between 100 ft$^3$/s and 1,200 ft$^3$/s. Maximum and minimum average daily flows during this time period ranged from a low of 22 ft$^3$/s to a high of 3,400 ft$^3$/s.

Nakwasina River is known locally for its freshwater sport fisheries for coho salmon and Dolly Varden *Salvelinus malma*. As Nakwasina River is easily accessed by boat and supports one of the largest populations of coho salmon in Sitka Sound, it is one of the few rivers near Sitka that attracts freshwater sport fishing effort for coho salmon. Although the number of respondents was low in the Statewide Harvest Survey (SWHS), estimated annual harvests of coho salmon in Nakwasina Sound, including Nakwasina River, ranged from 0 to 182 fish between 1984 and 2004 (Howe et al. 1995-1996, 2001a-d; Jennings et al. 2004, 2006a-b, 2007; Mills 1985-1994; Walker et al. 2003). Estimated angler effort expended in Nakwasina Sound and River (for all fish species) ranged from 31 to 891 angler days. Anecdotal information suggests that the harvest in the freshwaters of Nakwasina River may be a couple hundred fish annually.

Since 1980, visual surveys have been conducted by foot on Nakwasina River to provide an indication of trends in the annual abundance of coho salmon. Annual peak counts in Nakwasina River represent the largest of 5 systems surveyed in the Sitka area. Surveys conducted from 1980 to 2006 observed a range of adult coho salmon spawners between 47 (1986) and 996 (2006) (Table 2 ).

# METHODS

## SMOLT TAGGING AND SAMPLING

From April 15 to May 19, 2004, and April 14 to May 20, 2005, between 50 and 100 G-40 minnow traps were baited with salmon roe and fished daily in Nakwasina River. Traps were fished 24 hours per day, approximately 6 days per week and checked at least once each day. Traps were set along mainstem banks and in backwater areas of the lower river between the estuary and approximately 6 km upstream. Traps were distributed and redistributed opportunistically to maximize catch by targeting areas of likely rearing habitat, unfished areas, and areas known to produce relatively high catch rates. After the first day of trapping each year, captured fish were examined to determine an appropriate minimum tagging length. Generally, most fish were of a uniform length and exhibited a natural size break between young-of-the-year and age-1 fish. Coho salmon smolt in 2004 ≥70 mm FL and ≥65 mm FL in 2005 were removed from minnow traps and transported to holding pens at the campsite each day. Other species (primarily Dolly Varden) and small coho fry (<70 mm FL in 2004 and <65 mm FL in 2005) were counted and released onsite.

Every 2–3 days, all live coho salmon smolt were tranquilized with a solution of tricane methane-sulfonate (MS-222) and injected with a CWT. Fish were then marked externally by excising the adipose fin. Tagging and marking followed the methods of Koerner (1977) and Magnus et al. (2006). All tagged fish were held overnight in a net pen to test for mortality, tag retention, and adipose finclip status prior to release. To test for tag retention, 100 fish were randomly selected and passed through a Northwest Marine Mark IV Portable Sampling Detector™[1]. If tag retention was 98% or greater, all fish were counted, mortalities recorded, and released. If tag retention was 97% or less, untagged fish were retagged. The number of fish tagged, number of tagging-related mortalities, and number of fish that had shed their tags were recorded on *ADF&G Tagging Summary and Release Information Forms* that were submitted to ADF&G Commercial Fisheries Division (CFD) Mark, Tag and Age Laboratory (Tag Lab) in Juneau when fieldwork ended.

Three separate tag codes were used to identify different components of the smolt run. Small

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[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

Table 2.–Peak escapement counts of coho salmon in the Sitka area, 1980–2006.

| | Sinitsin Creek | | | St. John Baptist Bay Creek | | | Starrigavan River | | | Eagle River | | | Black River | | | Nakwasina River | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Survey type | Peak survey date | No. of Coho | Survey type | Peak survey date | No. of Coho | Survey type | Peak survey date | No. of Coho | Survey type | Peak survey date | No. of Coho | Survey type | Peak survey date | No. of Coho | Survey type | Peak survey date | No. of Coho |
| 1980 | Foot | 30 Sep | 39 | Foot | 9 Oct | 26 | Foot | | | Foot | 7 Oct | 9 | Foot | 26 Oct | 328 | Foot | 29-Oct | 70 |
| 1981 | Foot | 6 Oct | 85 | Foot | 14 Oct | 51 | Foot | 20 Oct | 170 | Foot | 17 Oct | 28 | | | | Foot | 7-Oct | 780 |
| 1982 | Foot | 20 Oct | 46 | Foot | | | Foot | 21 -Oct | 317 | | | | | | | | | |
| 1983 | Foot | 27 Sep | 31 | Foot | 13 Oct | 20 | Foot | 6 Oct | 45 | | | | | | | Foot | 14 Oct | 217 |
| 1984 | Foot | 10 Oct | 160 | Foot | 10 Oct | 154 | Foot | 10 Oct | 385 | Foot | 16 Oct | 7 | Helo | 3 Oct | 425 | Foot | 17 Oct | 715 |
| 1985 | Foot | 15 Oct | 144 | Foot | 8 Oct | 109 | Foot | 11 Oct | 193 | Foot | 9 Sep | 61 | Helo | 7 Oct | 1,628 | Foot | 7 Oct | 408 |
| 1986 | Foot | 30 Sep | 4 | Foot | 10 Oct | 9 | Foot | 10 Oct | 57 | Foot | 26 Sep | 245 | Helo | 10 Oct | 312 | Foot | 28 Oct | 275 |
| 1987 | Foot | 23 Sep | 21 | Foot | 23 Sep | 4 | Foot | 9 Oct | 36 | Foot | 24 Sep | 167 | Helo | 9 Oct | 262 | Foot | 30 Oct | 47 |
| 1988 | Foot | 3 Oct | 56 | Foot | 3 Oct | 71 | Foot | 12 Oct | 45 | Foot | 2 Sep | 10 | Helo | 10 Oct | 280 | Foot | 27 Oct | 104 |
| 1989 | Foot | 5 Oct | 76 | Foot | 5 Oct | 89 | Foot | 13 Oct | 101 | Weir | 2 Oct | 131 | Helo | 13 Oct | 181 | Foot | 19 Oct | 129 |
| 1990 | Foot | 1 Oct | 80 | Foot | 1 Oct | 38 | Foot | 17 Oct | 39 | Snorkel | 2 Oct | 214 | Helo | 4 Oct | 842 | Foot | 31 Oct | 195 |
| 1991 | Foot | 1 Oct | 186 | Foot | 10 Oct | 107 | Foot | 2 Oct | 142 | Snorkel | 17 Oct | 454 | Helo | 17 Oct | 690 | Foot | 25 Oct | 621 |
| 1992 | Foot | 23 Sep | 265 | Foot | 14 Oct | 110 | Foot | 12 Oct | 241 | Snorkel | 6 Oct | 629 | Helo | 6 Oct | 866 | Foot | 30 Oct | 654 |
| 1993 | Foot | 7 Oct | 213 | Foot | 6 Oct | 90 | Foot | 13 Oct | 256 | Snorkel | 13 Oct | 513 | Helo | 7 Oct | 764 | | | |
| 1994 | Foot | 30 Sep | 313 | Foot | 30 Sep | 227 | Foot | 11 Oct | 304 | Snorkel | 1 Oct | 717 | Helo | 14 Oct | 758 | Foot | 14 Oct | 404 |
| 1995 | Foot | 26 Sep | 152 | Foot | 5 Oct | 99 | Foot | 6 Oct | 274 | Snorkel | 5 Oct | 336 | Helo | 27 Sep | 1,265 | Foot | 29 Sep | 626 |
| 1996 | Foot | 2 Oct | 150 | Snorkel | 2 Oct | 201 | Foot | 17 Oct | 59 | Snorkel | 30 Sep | 488 | Helo | 30 Sep | 385 | Foot | 30 Oct | 553 |
| 1997 | Foot | 29 Sep | 90 | Snorkel | 30 Sep | 68 | Foot | 27 Oct | 55 | Snorkel | 30 Sep | 296 | Helo | 30 Sep | 686 | Foot | 14 Nov | 239 |
| 1998 | Foot | 1 Oct | 109 | Snorkel | 9 Oct | 57 | Foot | 8 Oct | 123 | Snorkel | 9 Oct | 300 | Helo | 8 Oct | 1,520 | Foot | 2 Nov | 653 |
| 1999 | Snorkel | 11 Oct | 48 | Snorkel | 29 Oct | 27 | Snorkel | 8 Oct | 167 | | | | Helo | 4 Oct | 1,590 | Snorkel | 12 Nov | 291 |
| 2000 | Foot | 26 Sep | 62 | Snorkel | 26 Oct | 32 | Snorkel | 8 Oct | 144 | Snorkel | 29 Sep | 108 | Helo | 2 Oct | 880 | Foot | 8 Nov | 419 |
| 2001 | Foot | 5 Oct | 132 | Snorkel | 4 Oct | 80 | Snorkel | 8 Oct | 133 | Snorkel | 4 Oct | 417 | Helo | 4 Oct | 1,080 | Foot | 14 Nov | 753 |
| 2002 | Foot | 10 Oct | 169 | Snorkel | 2 Oct | 100 | Foot | 10 Oct | 227 | Snorkel | 10 Oct | 659 | Helo | 3 Oct | 1,994 | Foot | 5 Nov | 713 |
| 2003 | Foot | 29 Sep | 102 | Snorkel | 30 Sep | 91 | Foot | 2 Oct | 95 | Snorkel | 9 Oct | 373 | Helo | 2 Oct | 1,055 | Foot | 31 Oct | 440 |
| 2004 | Foot | 3 Oct | 112 | Snorkel | 1 Oct | 80 | Foot | 2 Oct | 143 | Snorkel | 11 Oct | 391 | Helo | 7 Oct | 380 | Foot | 8 Nov | 399 |
| 2005 | Foot | 4 Oct | 67 | Snorkel | 14 Oct | 173 | Foot | 7 Oct | 76 | Snorkel | 14 Oct | 460 | Helo | 6 Oct | 106 | Foot | 7 Nov | 892 |
| 2006 | Foot | 1 Oct | 152 | Snorkel | 1 Oct | 121 | Foot | 8 Oct | 386 | Snorkel | 12 Oct | 992 | Helo | 12 Oct | 1,100 | Foot | 6 Nov | 996 |
| Mean (1980–2006) | | | 113 | | | 86 | | | 162 | | | 334 | | | 807 | | | 464 |
| 5-yr mean (200–2006) | | | 120 | | | 113 | | | 185 | | | 575 | | | 927 | | | 688 |

smolt (≥70 mm in 2004 and ≥65 mm in 2005 but less than 85 mm FL) were tagged with codes 04-08-66 in 2004 and 04-10-03 in 2005, while large smolt (≥85 mm FL) were tagged with codes 04-08-67 and 04-10-04. These tag codes were used to identify potential differential survival based on size at smolting. A third tag code (04-08-68 in 2004 and 04-10-05 in 2005) was used for all fish ≥65 mm or ≥70 mm that were captured in an unnamed tributary to Nakwasina (Figure 1) that is connected only intermittently. This tributary, referred to as "Bridge Creek," empties into salt water approximately ½ km from the outlet of Nakwasina River, except at high tides when the two appear to be connected by a small freshwater passage. This third tag code was used to determine if fish emigrating from this tributary spawn in the mainstem of Nakwasina and to examine differential survival by location of capture.

Smolt were measured to the nearest 1 mm FL, weighed to the nearest 0.1 g, and sampled for scales. Twelve to 15 scales were removed from the preferred area on the left side of the coho salmon smolt (Scarnecchia 1979). Scales were sandwiched between two 1x 3-in microscope slides and numbered consecutively for each sampled fish. Slides were taped together and the number and length of each fish was written on the frosted portion of the bottom slide according to scale position on the slide. Ages were determined postseason.

## INSTREAM MARK–RECAPTURE SAMPLING, CODED WIRE TAG RECOVERY, AND MARINE HARVEST SAMPLING

Each fall in 2005 and 2006, an open population mark–recapture experiment was used to estimate escapement. This was done in conjunction with CWT recovery efforts that provided information for estimation of smolt abundance with a closed population model.

Sampling occurred during 2- or 3-day periods once each week from September 9 through December 6, 2005, and August 30 through December 11, 2006. Adult coho salmon were captured using a 3.6 x 22.5 m, 3.75 cm mesh beach seine and a 3.0 x 35 m, 7.5 cm mesh gillnet.

Hook and line gear was also used to supplement net captures. Carcasses were sampled opportunistically when observed.

The stream was divided into 4 sections (Figure 1). Section 1 extended from river kilometer (rkm) 7.75 downstream to rkm 4.1. The portion of the river upstream of rkm 7.75 was not included because few fish have been observed in this section, and the presence of excessive amounts of woody debris and undercut banks were not conducive to capturing fish. Section 2 extended from rkm 4.1 downstream to rkm 3.7, and section 3 extended from rkm 3.7 to rkm 3.4. Section 4 extended from rkm 3.4 to tidewater. Sampling was concentrated in sections 2 and 3 because 2 large pools located there contained the majority of adult coho salmon visible in the river at any given time. These pools enabled effective deployment of the beach seine and gillnet.

All coho salmon captured were examined for presence or absence of their adipose fin. Initially, every coho salmon lacking an adipose fin was sacrificed, and its head was removed and sent to the Tag Lab for dissection and decoding. After a sufficient number of adipose-clipped individuals had been sacrificed to ensure desired statistical accuracy, sacrifices were reduced to every other coho lacking an adipose fin. This was done to minimize the removal of adult spawners. All captured coho salmon were also examined for an anchor tag and opercle punch combination. All coho salmon absent this combination were measured to the nearest mm FL, tagged with uniquely numbered Floy™ T-Bar anchor tag, given a secondary mark (opercle punch) to permit estimation of tag loss, examined to determine sex and condition, and sampled to collect scales for aging. Tags were inserted 1 cm below the insertion of the dorsal fin on the left side of the fish. Secondary marks were varied weekly to allow for reconstruction of capture histories in the event Floy™ tags were lost between sampling events. Secondary marks included various combinations of opercle punches that consisted of 0.6 cm diameter holes. The condition of each fish was determined from external characteristics using the following convention:

1. Bright    Ocean bright or nearly ocean bright;

6

2. Blush        Some color (primarily blush red);

3. Dark        Dark color (primarily red);

4. LPS (live post-spawner)   Spawned out but not yet dead;

5. Carcass       Dead spawned fish; and,

6. Mortality    Dead unspawned fish.

For fish recaptured with a Floy™ tag, the section, gear used, tag number, and condition were recorded and the fish was released. If an opercle punch but no anchor tag was present, the fish was recorded as a valid tag recovery (indicating the tag was shed), retagged, and examined for condition.

All carcasses that could be retrieved were also inspected for marks and recorded, and heads were removed if the adipose fin was missing. The left side of carcasses was slashed to prevent double sampling.

Sex was determined from external characteristics. Scale samples, consisting of 4 scales from the preferred area near the lateral line on an imaginary line from the insertion of the posterior dorsal fin to the anterior origin of the anal fin (Scarnecchia 1979), were collected and affixed to a gum card in the field. Postseason, scale images were impressed on acetate and ages were determined by examining the impressions under a microscope. Criteria used to assign ages were similar to those of Moser (1968).

Harvest of coho salmon originating from Nakwasina River was estimated from fish sampled in both commercial and marine sport fisheries. Fisheries personnel with the ADF&G CFD port-sampling program examined commercially-caught fish at processing locations and recovered coho salmon with missing adipose fins (Oliver *Unpublished*). Similarly, the Division of Sport Fish employed a creel survey program to examine fish caught in the sport fishery (e.g., see Hubartt et al. 2002). When possible, heads of fish without an adipose fin were removed and sent to the Tag Lab for tag detection and decoding. Because multiple fisheries exploited coho salmon over several months, harvest was estimated over several strata, each a combination of time, area, and type of fishery. Statistics from the commercial troll fishery were stratified by fishing period and by fishing quadrant. Statistics from the marine sport fishery were stratified bi-weekly.

## FOOT SURVEY COUNTS

Adult coho salmon in Nakwasina River were counted approximately every other week during October and November each year. Visual counts were conducted by 2 experienced observers either during or 1 day after instream sampling efforts. Only fish positively identified as coho salmon were counted. Counts were conducted between the uppermost portion of the survey area (rkm 7.75) and a pool near the high tide mark at rkm 0.25. Uncontrolled variables included observer abilities, weather conditions, and water clarity. Weather conditions, water clarity, and counts were recorded by stream section.

Bridge Creek was examined opportunistically during the course of sampling to determine if coho salmon used it for spawning or rearing.

## ESTIMATE OF SMOLT ABUNDANCE AND SIZE

Chapman's modification of the Petersen estimator (Seber 1982) was used to estimate smolt abundance. Several conditions must be met for unbiased estimates:

1. there is no recruitment or immigration to the population—only fish that were present in the population during the marking event are present in the population of fish inspected for marks as adults;

2. there is no tagging induced behavior or mortality—tagged fish behave the same as untagged fish after the marking event;

3. fish do not lose their marks and all marks are recognizable;

4. tag codes and release locations can be correctly determined for all adult fish observed with missing adipose fins; and

5. all fish marked as juveniles are smolt.

In addition, at least one set of conditions on mortality and sampling must be met. Because significant mortality occurs between sampling events, these conditions must be evaluated and satisfied concurrently. At least one of the following sets of conditions must be met:

S1. all fish have an equal probability of being captured and marked during the first event; or

S2. all fish have the same probability of surviving between events whether marked or unmarked and across all tagging groups and complete mixing of marked and unmarked fish occurs prior to the second event; or

S3. all fish have the same probability of surviving between events whether marked or unmarked and across all tagging groups and all fish have an equal probability of being captured and inspected for marks during the second event.

These conditions were evaluated, where possible, using experimental data and in some cases by indirect knowledge, or were ensured by exercising control over experimental procedures. Equal survival between tagging groups was evaluated using contingency table analysis to test for lack of independence between tagging group and probability of recovery during adult sampling. Contingency table analysis was also used to test for lack of independence between sampling events and freshwater age.

Estimates of mean smolt length and weight-at-age and their variances were calculated with standard sample summary statistics (Cochran 1977).

## ESTIMATE OF HARVEST

The contribution ($r_{ij}$) of release group $j$ to a fishery stratum $i$ was estimated as:

$$\hat{r}_{ij} = N_i \left[ \frac{m_{ij}}{\lambda_i n_i} \right] \theta_j^{-1}; \qquad \lambda_i = \frac{a_i' t_i'}{a_i t_i} \qquad (1)$$

where:

$N_i$  = total harvest in fishery stratum i,
$n_i$  = number of fish inspected in fishery stratum i (the sample),
$a_i$  = number of fish which were missing an adipose fin,
$a_i'$ = number of heads that arrived at the Tag Lab,
$t_i$  = number of heads with CWTs detected,
$t_i'$ = number of CWTs that were dissected from heads and decoded,
$m_i$  = number of CWTs with code(s) of interest, and
$\theta_j$  = fraction of the cohort tagged with code(s) of interest.

When $N_i$ and $\theta_j$ are known without error, an unbiased estimate of the variance of $\hat{r}_{ij}$ can be calculated as shown by Clark and Bernard (1987). However, $N_i$ is estimated with error in sport fisheries, and $\theta_j$ is estimated with error on Nakwasina River since wild stocks are tagged. Because of these circumstances, estimates of the variance of $\hat{r}_{ij}$ based on large sample approximations were obtained using the appropriate equations in Bernard and Clark (1996).

The total harvest for a cohort was calculated as the sum of strata estimates:

$$\hat{H} = \sum_i \sum_j \hat{r}_{ij} \qquad (2)$$

$$Var\left[\hat{H}\right] = \sum_i \sum_j v\left[\hat{r}_{ij}\right] \qquad (3)$$

## SPAWNING ESCAPEMENT

The escapements of adult (age .1) coho salmon in Nakwasina River were estimated from a Jolly-Seber (JS) experiment (Seber 1982) using the model described by Schwarz et al. (1993). Sub-adult (age .0) coho salmon were much smaller than adults and were ignored. Weekly sampling trips spanning the time of immigration were conducted to mark and recapture adults. Following the work of Sykes and Botsford (1986), repeated recaptures of carcasses "captured" in a decayed condition were not included. Carcasses found were slashed along the left side to prevent double sampling.

In general, escapement ($E$) is the total number of immigrants ($B_i$) between the first and last sampling occasion, including fish that enter the system and die between any 2 sampling occasions ($i$), and fish that enter before the first sampling occasion ($B_0$) and after the last sampling occasion ($B_s$): $\hat{E} = \hat{B}_0 + ... + \hat{B}_{s-2} + \hat{B}_{s-1} + B_s$. Because sampling began early in immigration and continued until it was virtually over, $B_0 + B_1$ was estimated from an estimate of abundance just before the second JS sampling event ($\hat{N}_2$) and ignored immigration $B_{s+1}$ and beyond as suggested by Schwarz et al (1993). The resulting (albeit negatively biased) estimator is thus:

$$\hat{E} = \hat{N}_2\left(\frac{\log\hat{\phi}_1}{\hat{\phi}_1 - 1}\right) + \hat{B}_2\left(\frac{\log\hat{\phi}_2}{\hat{\phi}_2 - 1}\right) + \ldots + \hat{B}_{s-2}\left(\frac{\log\hat{\phi}_{s-2}}{\hat{\phi}_{s-2} - 1}\right) \qquad (4)$$

where $\hat{B}_i$ are JS estimates of the number of fish present at sample time $i+1$ that immigrated between $i$ and $i+1$, $\hat{\phi}_i$ is the survival rate from $i$ to $i+1$, and the factors $\frac{\log(\phi_i)}{\phi_i - 1}$ account for fish that enter and die between samples under the assumption that mortality is uniformly distributed between sampling events. The computer program POPAN (Arnason and Schwarz 1995) was used to estimate the JS parameters, and out-of-bounds estimates were constrained to admissible values (Schwarz et al. 1993; Schwarz and Arnason 1996). Variance of escapement was estimated using the delta method and the asymptotic variance and covariances in Schwarz et al. (1993), and expected values of the sampling statistics from POPAN.

Assumptions of the standard (full) JS model (Seber 1982) include:

1. every fish in the population has the same probability of capture in the $i^{th}$ sample;

2. every marked fish has the same probability of surviving from the $i^{th}$ to the $(i+1)^{th}$ sample and being in the population at the time of the $(i+1)^{th}$ sample;

3. every fish caught in the $i^{th}$ sample has the same probability of being returned to the population;

4. marked fish do not lose their marks between sampling events and all marks are reported on recovery; and

5. all samples are instantaneous (sampling time is negligible).

Chi-square goodness-of-fit tests were used to test for homogenous capture and survival probabilities by tagged status (Pollock et al. 1990). The first test is equivalent to the Robson (1969) test for short-term mortality. The second test is reported to be better at detecting heterogeneous survival probabilities (Pollock et al. 1990). The sum of the $\chi^2$ from each test is an overall test statistic for violations of the first 3 assumptions above (equal

probability of capture, survival, and return to the population).

The equal probability of capture assumption can also be violated if sampling is size or sex selective. Although differences in the size of adult coho salmon are small, a hypothesis that fish of different sizes were captured with equal probabilities was tested by using Kolmogorov-Smirnov (K-S) 2-sample tests (Conover 1980). Sex-selective sampling was investigated using contingency table analysis with a $\chi^2$ test statistic (Cochran 1977) comparing the number of males and females marked with those recaptured.

Assumptions 3, 4, and 5 were thought to be robust in this experiment. With regard to assumption 3, the only fish that are not returned to the experiment during sampling are those with missing adipose fin, indicating the presence of a coded wire tag. There is no reason to believe the presence or absence of a coded wire tag imbedded deep in cartilage has any effect on adult inriver survival, spawning activity, or the probability that a fish is captured during inriver sampling. With regard to assumption 4, the combination of opercle punch and anchor tag marks and diligent inspection of all fish sampled has been sufficient to ensure that an accurate capture history is recorded for each fish sampled. With regard to assumption 5, the ability to observe multiple recaptures over the course of the experiment indicates that fish persist in the sampling sections across several sampling events, so while sampling events occupy 2–3 days per week, the potential for bias due to sampling not being "instantaneous" is negligible.

## AGE AND SEX COMPOSITION

The proportion of the spawning population composed of a given age or sex was estimated as (Cochran 1977):

$$\hat{p}_j = \frac{n_j}{n} \qquad (5)$$

$$Var(\hat{p}_j) = \frac{\hat{p}_j(1 - \hat{p}_j)}{n - 1} \qquad (6)$$

where:

$p_j$ = the proportion in the population in group $j$;
$n_j$ = the number in the sample of group $j$; and
$n$ = sample size.

To reduce bias due to inseason changes in age composition, samples were obtained systematically.

## ESTIMATES OF TOTAL RUN, EXPLOITATION, AND MARINE SURVIVAL

Estimates of total run (i.e., harvest and escapement) for coho salmon returning to Nakwasina River in 2005 and 2006 and the associated exploitation rate in commercial and sport fisheries are based on the sum of the estimated harvest and escapement:

$$\hat{N}_R = \hat{H} + \hat{E} \qquad (7)$$

The variance of the estimated run was calculated as the sum of the variances for estimated escapement and harvest:

$$Var[\hat{N}_R] = Var[\hat{H}] + Var[\hat{E}] \qquad (8)$$

The estimate of exploitation rate and variance were calculated using (Mood et al. 1974):

$$\hat{U} = \frac{\hat{H}}{\hat{N}_R} \qquad (9)$$

$$Var[\hat{U}] \approx \frac{Var[\hat{H}]\hat{E}^2}{\hat{N}_R^4} + \frac{Var[\hat{E}]\hat{H}^2}{\hat{N}_R^4} \qquad (10)$$

The estimated survival rate of smolt to adults and variance were calculated using (Mood et al. 1974):

$$\hat{S} = \frac{\hat{N}_R}{\hat{N}_s} \qquad (11)$$

$$Var[\hat{S}] \approx \hat{S}^2 \left[ \frac{Var[\hat{N}_R]}{\hat{N}_R^2} + \frac{Var[\hat{N}_s]}{\hat{N}_s^2} \right] \qquad (12)$$

# RESULTS

## SMOLT TAGGING, SAMPLING, AND ABUNDANCE

### 2004

Smolt abundance in 2004 was estimated to be 47,573 (SE = 3,039). From April 15 to May 19, 2004, 9,796 coho smolt from Nakwasina River and its tributaries were captured and marked with a CWT. Tag retention was 100.0% with 25 overnight mortalities. This left 9,771 valid tag releases. Of these, 5,165 (52.9%) were small smolt captured in the mainstem of Nakwasina River (Table 3), while 2,692 (27.5%) were large smolt. Twenty percent (19.6%), or 1,914, were fish ≥70 mm captured in Bridge Creek.

Smolt captured in the mainstem of Nakwasina River that were age-1. fish (those rearing for one year in fresh water) comprised 98% of sampled smolt and averaged 83.1 mm FL (SE = 0.53) and 5.7 g (SE = 0.13, Table 4). Age-2. coho smolt from mainstem Nakwasina averaged 99.3 mm FL (SE = 2.18) and 9.3 g (SE = 0.79). The combined catch averaged 83.4 mm FL (SE = 0.53) and 5.8 g (SE = 0.13). Average length and weight of captured coho remained approximately the same throughout the tagging effort.

Age-1. fish from Bridge Creek comprised 99% of sampled smolt and averaged 86.3 mm FL (SE = 1.10) and 6.5 g (SE = 0.28, Table 4). One age-2. coho smolt was sampled from Bridge Creek and measured 108 mm and weighed 11.2 g.

The proportions of smolt tagged in 2004 with each of 3 tag codes were not significantly different than that observed in the spawning escapement in 2005 ($\chi^2$ = 0.51, P = 0.775, Table 3). Additionally, no differences were detected when large and small smolt from Nakwasina River were combined and compared to those tagged in Bridge Creek ($\chi^2$ = 1.51, P = 0.219, Table 3). The tag groups of large and small Nakwasina River smolt had similar survival based on rates of recovery of tagged adult fish ($\chi^2$ = 0.34, P = 0.560, Table 3). Tagged adults from Bridge Creek were included to estimate smolt abundance because their survival was similar to fish tagged in Nakwasina River.

Table 3.–Numbers and χ2 tests for independence for smolt and adult coho salmon from the Nakwasina River and Bridge Creek, 2000–2006.

| Year | ≥70 mm[a] | ≥85 mm | Bridge Creek | Total | ≥70 mm[a] | ≥85 mm | Bridge Creek |
|---|---|---|---|---|---|---|---|
| Spring smolt releases | | | | | Percentage of Total | | |
| 2000 | 5,446 | 1,831 | 3,042 | 10,319 | 53% | 18% | 29% |
| 2001 | 6,979 | 1,434 | 1,986 | 10,399 | 67% | 14% | 19% |
| 2002 | 3,566 | 874 | 1,246 | 5,686 | 63% | 15% | 22% |
| 2003 | 9,925 | 2,533 | 3,304 | 15,762 | 63% | 16% | 21% |
| 2004 | 5,165 | 2,692 | 1,914 | 9,771 | 53% | 28% | 20% |
| 2005 | 7,158 | 2,083 | 3,748 | 12,989 | 55% | 16% | 29% |
| Adult escapement recoveries | | | | | | | |
| 2001 | 75 | 35 | 40 | 150 | 50% | 23% | 27% |
| 2002 | 146 | 39 | 15 | 200 | 73% | 20% | 8% |
| 2003 | 145 | 28 | 24 | 197 | 74% | 14% | 12% |
| 2004 | 180 | 77 | 44 | 301 | 60% | 26% | 15% |
| 2005 | 87 | 48 | 37 | 172 | 51% | 28% | 22% |
| 2006 | 100 | 21 | 44 | 165 | 61% | 13% | 27% |
| Adult fisheries recoveries | | | | | | | |
| 2001 | 48 | 22 | 29 | 99 | 48% | 22% | 29% |
| 2002 | 27 | 22 | 5 | 54 | 50% | 41% | 9% |
| 2003 | 28 | 8 | 14 | 50 | 56% | 16% | 28% |
| 2004 | 52 | 22 | 24 | 98 | 53% | 22% | 24% |
| 2005 | 45 | 15 | 20 | 80 | 60% | 26% | 15% |
| 2006 | 28 | 16 | 37 | 81 | 35% | 20% | 46% |
| All adults combined | | | | | | | |
| 2001 | 123 | 57 | 69 | 249 | 49% | 23% | 28% |
| 2002 | 173 | 61 | 20 | 254 | 68% | 24% | 8% |
| 2003 | 173 | 36 | 38 | 247 | 70% | 15% | 15% |
| 2004 | 232 | 99 | 68 | 399 | 58% | 25% | 17% |
| 2005 | 132 | 63 | 57 | 252 | 60% | 26% | 15% |
| 2006 | 128 | 37 | 81 | 246 | 52% | 15% | 33% |

| Component 1 | Component 2 | χ2 | p |
|---|---|---|---|
| Nakwasina smolt 2000 | All adults 2001 | 4.63 | 0.099 |
| Nakwasina smolt 2000 | Adult escapement 2001 | 3.11 | 0.191 |
| Adult fisheries 2001 | Adult escapement 2001 | 0.21 | 0.901 |
| Smolt 2001 | All adults 2002 | 36.95 | 0.000 |
| Smolt 2001 | Adult escapement 2002 | 20.24 | 0.000 |
| Adult fisheries 2002 | Adult escapement 2002 | 11.46 | 0.003 |
| Smolt 2002 | All adults 2003 | 7.34 | 0.026 |
| Smolt 2002 | Adult escapement 2003 | 12.85 | 0.002 |
| Adult fisheries 2003 | Adult escapement 2003 | 8.34 | 0.016 |
| Nakwasina smolt 2002 | Nakwasina adults 2003 | 0.84 | 0.360 |
| Nakwasina smolt 2002 | Nakwasina escapement 2003 | 1.39 | 0.238 |
| Nakwasina fisheries 2003 | Nakwasina escapement 2003 | 0.76 | 0.383 |
| Adult fisheries 2004 | Adult escapement 2004 | 5.10 | 0.078 |
| Nakwasina smolt 2003 | Nakwasina adults 2004 | 23.98 | 0.000 |
| Nakwasina smolt 2003 | Nakwasina escapement 2004 | 23.65 | 0.000 |
| Nakwasina smolt 2003 | Bridge Creek smolt 2003 | 3.62 | 0.057 |
| Nakwasina small smolt 2003 | Nakwasina large smolt 2003 | 18.09 | 0.000 |
| Nakwasina fisheries 2004 | Nakwasina escapement 2004 | 5.10 | 0.078 |
| Nakwasina smolt 2004 | Nakwasina adults 2005 | 1.84 | 0.400 |
| Nakwasina smolt 2004 | Nakwasina escapement 2005 | 0.51 | 0.775 |
| Nakwasina smolt 2004 | Bridge Creek smolt 2004 | 1.51 | 0.219 |
| Nakwasina small smolt 2004 | Nakwasina large smolt 2004 | 0.34 | 0.560 |
| Nakwasina fisheries 2005 | Nakwasina escapement 2005 | 2.155 | 0.342 |
| Nakwasina smolt 2005 | Nakwasina adults 2006 | 2.03 | 0.363 |
| Nakwasina smolt 2005 | Nakwasina escapement 2006 | 2.34 | 0.311 |
| Nakwasina smolt 2005 | Bridge Creek smolt 2005 | 2.03 | 0.155 |
| Nakwasina small smolt 2005 | Nakwasina large smolt 2005 | 1.89 | 0.169 |
| Nakwasina fisheries 2006 | Nakwasina escapement 2006 | 13.17 | 0.001 |

[a] In 2003 and 2005 smolt ≥65 mm were tagged.

Table 4.–Estimated fork length, weight, and age of coho salmon smolt from Nakwasina River and Bridge Creek in 2004 and 2005.

| | 2004[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nakwasina | | | | | | Bridge Creek | | | |
| | Age-1. | | Age-2. | | Combined | | Age-1. | | Age-2. | |
| Statistic | Length[b] | Weight[b] | Length | Weight | Length | Weight | Length | Weight | Length | Weight |
| Mean | 83.13 | 5.74 | 99.25 | 9.25 | 83.37 | 5.79 | 86.34 | 6.49 | 108 | 11.2 |
| SE | 0.527 | 0.125 | 2.175 | 0.786 | 0.533 | 0.127 | 1.096 | 0.280 | - | - |
| Sample size | 266 | 265 | 4 | 4 | 270 | 269 | 76 | 76 | 1 | 1 |
| | 2005 [a] | | | | | | | | | |
| | Nakwasina | | | | | | Bridge Creek | | | |
| | Age-1. | | Age-2. | | Combined | | Age-1. | | Age-2. | |
| Statistic | Length[b] | Weight[b] | Length | Weight | Length | Weight | Length | Weight | Length | Weight |
| Mean | 78.57 | 4.92 | 108.50 | 12.75 | 78.74 | 4.97 | 83.52 | 5.61 | - | - |
| SE | 0.509 | 0.101 | 3.500 | 1.950 | 0.521 | 0.105 | 0.762 | 0.157 | - | - |
| Sample size | 347 | 347 | 2 | 2 | 349 | 349 | 145 | 145 | - | - |

[a]   Minimum tagging size was 70 mm FL in 2004 and 65 mm FL in 2005.

[b]   Length measured to the nearest mm FL and weight to the nearest 0.10 g.

## 2005

Smolt abundance in 2005 was estimated to be 64,164 (SE = 3,105). Between April 14 and May 20, 2005, 13,024 coho smolt from Nakwasina River and its tributaries were captured and marked with a CWT. Tag retention was 99.9% with 30 overnight mortalities. This left 12,989 valid tag releases. Of these, 7,158 (55.1%) were small smolt captured in the mainstem of Nakwasina River, while 2,083 (16.0%) were large smolt (Table 3). Twenty-nine percent (28.9%), or 3,748 were fish ≥65 mm captured in Bridge Creek.

Smolt captured in the mainstem of Nakwasina River that were age-1. fish comprised 99% of sampled smolt and averaged 78.6 mm FL (SE = 0.51) and 4.9 g (SE = 0.10, Table 4). Age-2. coho smolt from mainstem Nakwasina averaged 108.5 mm FL (SE = 3.5) and 12.8 g (SE = 1.95). The combined catch averaged 78.7 mm FL (SE = 0.52) and 5.0 g (SE = 0.11). Average length and weight of captured coho remained approximately the same throughout the tagging effort.

Age-1. fish from Bridge Creek comprised 100% of sampled smolt and averaged 83.5 mm FL (SE = 7.6) and 5.6 g (SE = 0.16, Table 4).

The proportions of smolt tagged in 2005 with each of 3 tag codes were not significantly different than that observed in the spawning escapement in 2006 ($\chi^2$ = 2.34, P < 0.311, Table 3). Additionally, no differences were detected when large and small smolt from Nakwasina were combined and compared to those tagged in Bridge Creek ($\chi^2$ = 2.03, P = 0.155, Table 3). The tag groups of large and small Nakwasina River smolt had similar survival based on rates of recovery of tagged adult fish ($\chi^2$ = 1.89, P = 0.169, Table 3). Tagged adults from Bridge Creek were included to estimate smolt abundance because their survival was similar to fish tagged in Nakwasina River.

## INSTREAM CODED WIRE TAG RECOVERY AND AGE-SEX COMPOSITION

### 2005

The CWT marked fraction of adult coho salmon sampled in Nakwasina River during 2005 was 0.205. Of the 921 adult coho salmon examined, 189 had an adipose finclip. Of these, 9 did not contain a coded wire tag and 8 were released alive.

The proportion of freshwater age-1. fish was not significantly different ($\chi^2$ = 0.70, P = 0.404) between smolt sampled in 2004 and adults sampled inriver during 2005 (Table 5, Appendix A1). Both groups were predominately (>97%) freshwater age-1. fish. Additionally, no differences were detected in freshwater age by sex ($\chi^2$ = 0.73, P = 0.394).

### 2006

The CWT marked fraction of adult coho salmon sampled in Nakwasina River during 2006 was 0.202. Of the 1,634 adult coho salmon examined, 330 had an adipose finclip. Of these, 166 were sacrificed for tag analysis. Of the 166, 165 were successfully decoded and contained a valid Nakwasina River tag. One fish did not contain a coded wire tag. One hundred sixty-four (164) fish were released alive.

The proportion of freshwater age-1. fish was not significantly different ($\chi^2$ = 0.89, P = 0.345) between smolt sampled in 2005 and adults sampled inriver during 2006 (Table 5, Appendix A1). Both groups were predominately (>97%) freshwater age-1. fish. Additionally, no differences were detected in freshwater age by sex ($\chi^2$ = 1.99, P = 0.158).

## CONTRIBUTION TO MARINE FISHERIES

### 2005

The estimated harvest of Nakwasina River coho salmon in randomly sampled marine fisheries in 2005 was 1,796 (SE = 226, Table 6). Nakwasina coho contributed less than 1% of the combined sport, troll, and seine harvest (1,357,614, Table 6) for the areas in which Nakwasina River fish were recovered. The estimated total contribution to the marine sport fishery by Nakwasina coho was 138 fish. Sport-caught Nakwasina coho salmon comprised 12% (Figure 2) of total harvest of that stock in the sampled marine fisheries, but relative contributions were higher for the sport harvest (0.34%) than the troll harvest (0.12%). Estimates of freshwater harvest of coho salmon in Nakwasina River based on the SWHS are not considered reliable because of a low response rate. Anecdotal information, collected from angler

Table 5.–Number of age-1. and age-2. coho salmon smolt and adults, 2004–2006.

| | | Brood year and age class | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample year | | 2006 | | | | | 2005 | | |
| Brood year | | 2004 | 2003 | 2003 | 2002 | Total aged | 2002 | 2001 | Total aged |
| Age class | | 1.0 | 2.0 | 1.1 | 2.1 | | 1.1 | 2.1 | |
| Females | Sample size | - | - | 241 | 7 | 248 | 247 | 4 | 251 |
| | Percent | - | - | 97.2% | 2.8% | | 98.4% | 1.6% | |
| | SE | - | - | 1.1% | 1.1% | | 0.8% | 0.8% | |
| | Mean length | - | - | 650.0 | 663.6 | | 638.7 | 672.5 | |
| | SE | - | - | 2.3 | 20.3 | | 2.2 | 24.4 | |
| Males | Sample size | 15 | 1 | 388 | 5 | 393 | 373 | 10 | 383 |
| | Percent | 3.7% | 0.2% | 94.9% | 1.2% | | 97.4% | 2.6% | |
| | SE | 0.9% | 0.2% | 1.1% | 0.5% | | 0.8% | 0.8% | |
| | Mean length | 303.0 | 320.0 | 630.0 | 588.0 | | 622.2 | 620.0 | |
| | SE | 10.3 | - | 3.4 | 22.7 | | 2.2 | 24.3 | |
| All Fish | Sample size | 15 | 1 | 629 | 12 | 641 | 620 | 14 | 634 |
| | Percent | 2.3% | 0.2% | 95.7% | 1.8% | | 97.8% | 2.2% | |
| | SE | 0.6% | 0.2% | 0.8% | 0.5% | | 0.6% | 0.6% | |
| | Mean length | 303.0 | 320.0 | 637.9 | 632.1 | | 628.8 | 622.5 | |
| | SE | 10.3 | - | 2.3 | 18.3 | | 2.2 | 18.2 | |

| | Freshwater age[a] | | $\chi^2$ | P-value |
|---|---|---|---|---|
| | 1 | 2 | | |
| Adults 2005 | 620 | 14 | 0.70 | 0.4044 |
| Smolt 2004 | 342 | 5 | | |
| Adults 2006 | 630 | 14 | 0.89 | 0.3447 |
| Smolt 2005 | 488 | 7 | | |
| 2005 adult males | 373 | 10 | 0.73 | 0.3939 |
| 2005 adult females | 247 | 4 | | |
| 2006 adult males | 388 | 5 | 1.99 | 0.1584 |
| 2006 adult females | 241 | 7 | | |

[a]  Differences between $\chi^2$ observations and age class sample sizes are due to unreadability of fresh or saltwater ages.

Table 6.–Estimated harvest of adult Nakwasina River coho salmon in sport and commercial fisheries sampled in 2005 and 2006.

**2006**

**TROLL FISHERY**

| Period | Dates | Quadrant | Estimated harvest | Inspected | a | a' | t | t' | m | r | SE{r} |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 6/25–8/12 | NE | 103,856 | 28,143 | 312 | 308 | 205 | 205 | 1 | 19 | 18 |
| 3 | 8/14–9/10 | NW | 469,803 | 134,965 | 1,476 | 1,413 | 1,033 | 1,033 | 19 | 344 | 79 |
| 3 | 8/14–9/10 | SE | 74,432 | 24,050 | 211 | 202 | 124 | 124 | 2 | 32 | 22 |
| 4 | 8/13–9/7 | NE | 106,264 | 27,849 | 333 | 327 | 244 | 244 | 2 | 39 | 27 |
| 4 | 8/13–9/7 | NW | 405,754 | 96,590 | 1,568 | 1,519 | 1,270 | 1,269 | 32 | 692 | 124 |
| Subtotal troll fishery | | | 1,160,109 | 311,597 | 3,900 | 3,769 | 2,876 | 2,875 | 56 | 1,125 | 152 |

**SPORT FISHERY**

| Bi-week | Dates | Area | Estimated harvest | Inspected | a | a' | t | t' | m | r | SE{r} |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 7/14–7/15 | SITKA | 2,800 | 1,681 | 16 | 16 | 14 | 14 | 1 | 8 | 8 |
| 15 | 7/16–7/29 | SITKA | 10,000 | 3,250 | 32 | 32 | 23 | 23 | 5 | 77 | 33 |
| 16 | 7/30–8/12 | SITKA | 12,385 | 4,180 | 37 | 37 | 33 | 33 | 4 | 59 | 29 |
| 17 | 8/13–8/26 | SITKA | 10,590 | 4,805 | 44 | 44 | 38 | 38 | 5 | 55 | 24 |
| 18 | 8/27–9/9 | SITKA | 4,720 | 802 | 21 | 21 | 19 | 19 | 1 | 29 | 29 |
| 19 | 9/10–9/23 | SITKA | 610 | 110 | 2 | 2 | 2 | 2 | 2 | 55 | 38 |
| Subtotal sport fishery | | | 41,105 | 14,828 | 152 | 152 | 129 | 129 | 18 | 283 | 70 |
| Total all fisheries | | | 1,201,214 | 326,425 | 4,052 | 3,921 | 3,005 | 3,004 | 74 | 1,409 | 167 |

**2005**

**TROLL FISHERY**

| Period | Dates | Quadrant | Estimated harvest | Inspected | a | a' | t | t' | m | r | SE{r} |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 6/26–8/13 | NW | 646,267 | 181,111 | 2,238 | 2,194 | 1,614 | 1,609 | 19 | 339 | 79 |
| 4 | 8/14–9/10 | NE | 69,947 | 16,812 | 238 | 238 | 185 | 185 | 1 | 20 | 20 |
| 4 | 8/14–9/10 | NW | 405,055 | 102,640 | 1,420 | 1,404 | 1,131 | 1,128 | 22 | 430 | 93 |
| 4 | 8/14–9/10 | SE | 67,343 | 9,134 | 119 | 118 | 79 | 79 | 23 | 836 | 180 |
| 5 | 9/11–10/1 | NW | 127,713 | 39,415 | 737 | 729 | 571 | 571 | 1 | 16 | 16 |
| Subtotal troll fishery | | | 1,316,325 | 349,112 | 4,752 | 4,683 | 3,580 | 3,572 | 66 | 1,642 | 219 |

**PURSE SEINE FISHERY**

| Week | Dates | Quadrant | Estimated Harvest | Inspected | a | a' | t | t' | m | r | SE{r} |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | 8/14–8/20 | NW | 832 | 500 | 9 | 9 | 5 | 5 | 2 | 16 | 11 |
| Subtotal seine fishery | | | 832 | 500 | 9 | 9 | 5 | 5 | 2 | 16 | 11 |

**SPORT FISHERY**

| Bi-week | Dates | Area | Estimated Harvest | Inspected | a | a' | t | t' | m | r | SE{r} |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 8/1–8/14 | SITKA | 17,411 | 4,973 | 101 | 100 | 85 | 85 | 1 | 17 | 17 |
| 17 | 8/15–8/28 | SITKA | 16,823 | 5,161 | 66 | 65 | 61 | 61 | 5 | 81 | 35 |
| 18 | 8/29–9/11 | SITKA | 6,223 | 762 | 10 | 10 | 9 | 9 | 1 | 40 | 39 |
| Subtotal sport fishery | | | 40,457 | 10,896 | 177 | 175 | 155 | 155 | 7 | 138 | 56 |
| Total all fisheries | | | 1,357,614 | 360,508 | 4,938 | 4,867 | 3,740 | 3,732 | 75 | 1,796 | 226 |

15
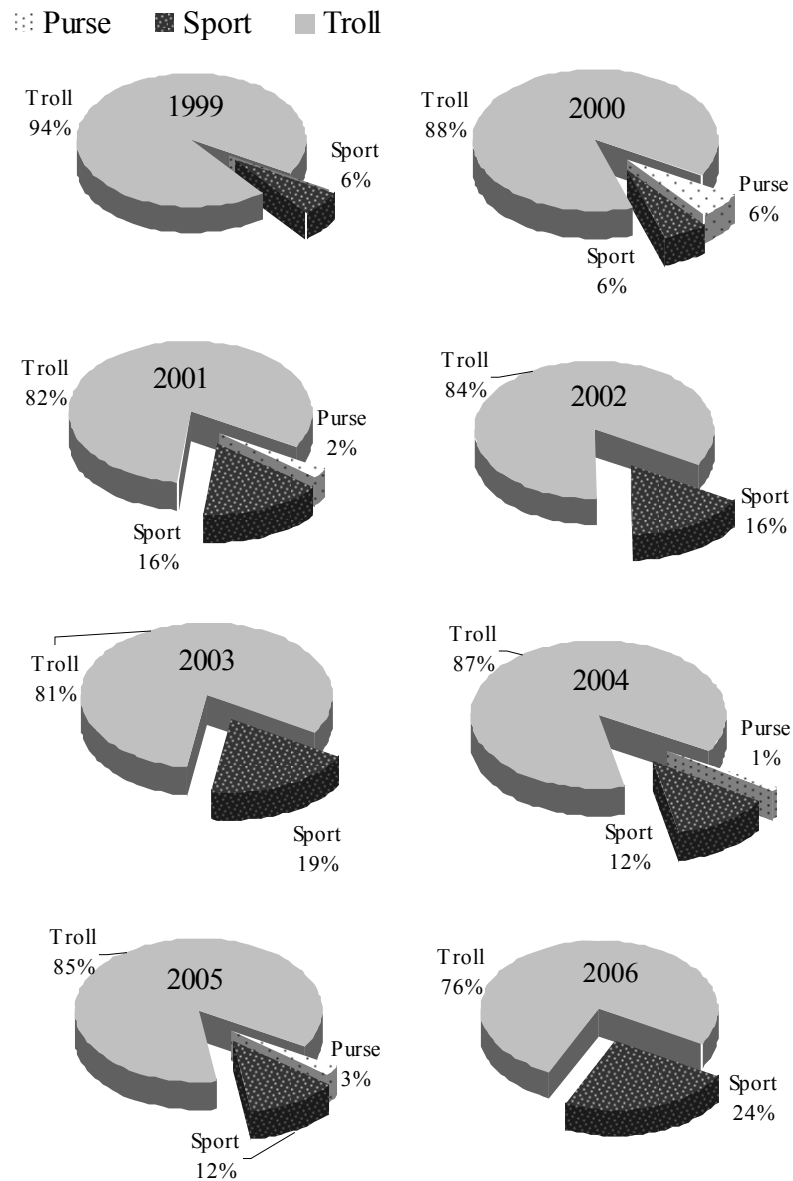
Figure 2.–Portion of Nakwasina coho harvest by fishery, 1999–2006.

reports and observation, suggests that in 2005 a few hundred fish were harvested in the freshwater of Nakwasina River.

In 2005, 77 CWTs from Nakwasina River and Bridge Creek were randomly recovered from 360,508 coho salmon sampled in commercial and sport fisheries and 2 additional CWTs were selectively recovered (Appendix A2). Sixty-six coho salmon bearing CWTs with a Nakwasina River code were recovered randomly from Southeast Alaska's commercial troll fisheries. Of

the 66 random troll fishery recoveries with quadrant information 42 were caught in the Northwest Quadrant (Figure 3) of Southeast Alaska between June 26 and October 1, 2005. Seven coho salmon bearing CWTs with a Nakwasina River code were recovered in the Sitka sport fishery between August 1 and September 11. Two fish were randomly recovered in the commercial seine fishery in the Northwest Quadrant in stat week 34. Two coho salmon bearing CWTs were recovered in the Yakutat
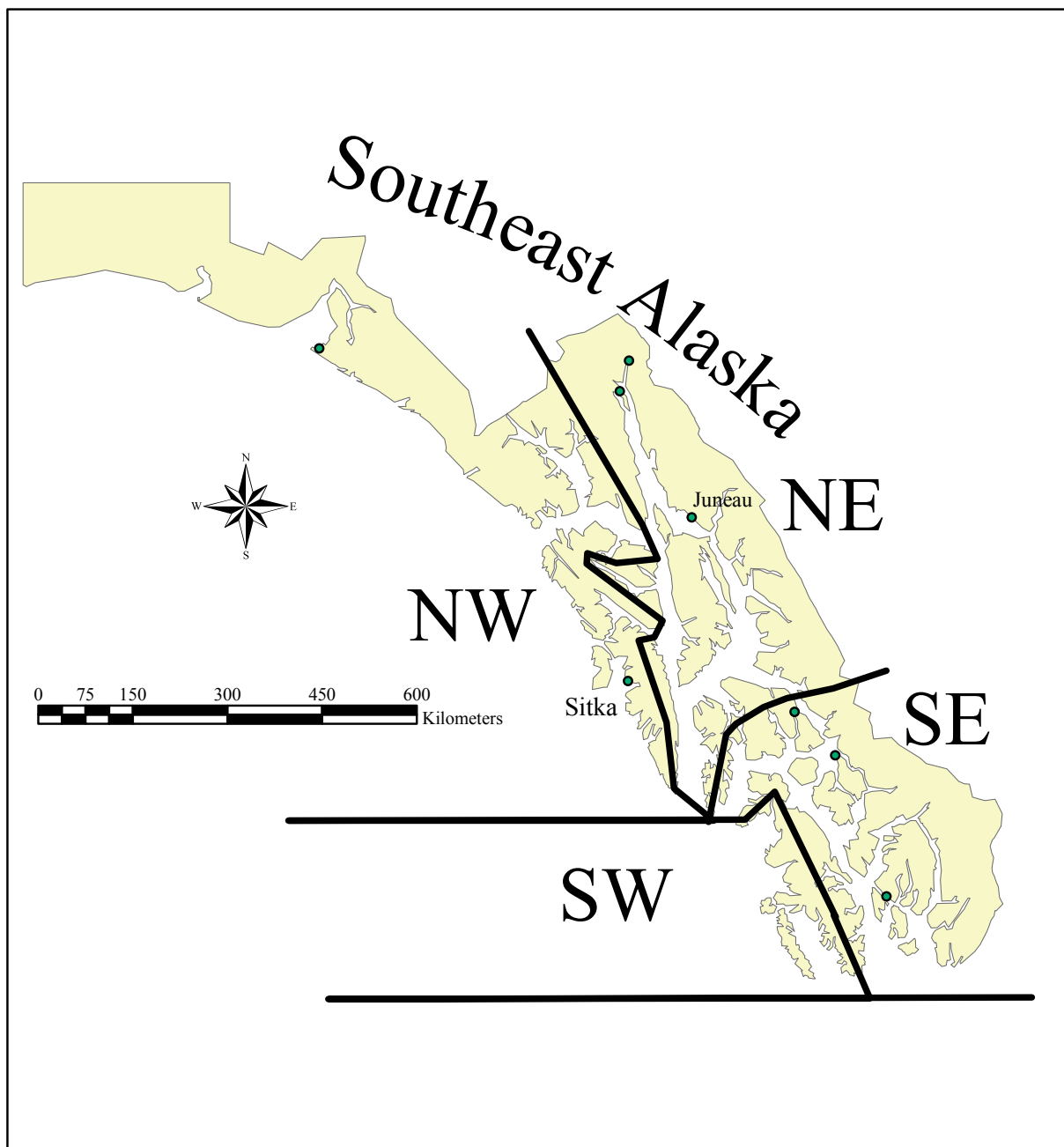
Figure 3.–Map of Southeast Alaska showing the boundaries for CWT quadrants.

sport fishery on September 3, 2005. Although these 2 fish were recovered randomly, the total catch and number samples were not available for that stratum. These 2 fish were not used in expanding harvest, but were added to the total estimated harvest along with one random recovery lacking quadrant data, and 2 selective recoveries making the total estimated harvest 1,801.

Coho salmon bearing CWTs with a Nakwasina River code recovered in the commercial and sport fisheries averaged 639 mm FL (SE = 5.12).

## 2006

The estimated harvest of Nakwasina River coho salmon in sampled marine fisheries in 2006 was 1,409 (SE = 167, Table 6). In 2006, 74 CWTs

from Nakwasina River and Bridge Creek were randomly recovered from 326,425 coho salmon sampled in the commercial and sport fisheries and 5 additional CWTs were selectively recovered (Appendix A2). Fifty-six coho salmon bearing CWTs with a Nakwasina River code were recovered randomly from Southeast Alaska's commercial troll fisheries, and an additional 2 fish were recovered that did not have associated quadrant data. Of the 56 random troll fishery recoveries with quadrant information, all but 5 were caught in the Northwest Quadrant (Figure 3) of Southeast Alaska between June 25 and September 7, 2006. Eighteen coho salmon bearing CWTs with a Nakwasina River code were recovered in the Sitka sport fishery between July 14 and September 11. The additional 5 selectively recovered fish and 2 fish without quadrant information were added to the harvest estimate to bring the total estimated harvest to 1,416.

Nakwasina coho contributed less than 1% of the combined sport, troll, and seine harvest (1,201,214, Table 6) for the areas in which Nakwasina River fish were recovered. The estimated total contribution to the marine sport fishery by Nakwasina coho was 283 fish. Sport-caught Nakwasina coho salmon comprised 24% of the harvest of that stock in the sampled marine fisheries (Figure 2), but relative contributions were higher for the sport harvest (0.69%) than the troll harvest (0.10%). Approximately 50% of recovered coded wire tagged coho of Nakwasina origin in marine fisheries are recovered by the third week in August annually (Figure 4). Estimates of freshwater harvest of coho salmon in Nakwasina River based on the SWHS are not considered reliable because of a low response rate. Anecdotal information, collected from angler reports and onsite observation, suggests that in 2006 a few hundred fish were harvested in the freshwater of Nakwasina River.

Coho salmon bearing CWTs with a Nakwasina River code recovered in the commercial and sport fisheries averaged 683 mm FL (SE = 5.77).

## ESTIMATED SPAWNING ESCAPEMENT, TOTAL RUN, AND MARINE SURVIVAL

### 2005

The estimated spawning escapement of coho salmon in Nakwasina River in 2005 was 3,539 fish (SE = 817). Coho salmon were marked and recaptured in all 13 weeks (September 9–December 6) of the study. Altogether, sampling resulted in 1,073 fish captures: 920 unique adults were captured and examined and 153 were recaptures (Table 7, Appendix A3). No recaptured fish lost their numbered tag as evidenced by the operculum punches. A total of 193 fish were sacrificed for their CWTs or died on capture and 1 fish died upon recapture. Most adult coho captured in Nakwasina River in 2005 were captured with either the beach seine or gillnet, while 90 were captured with hook-and-line. Hook-and-line gear was moderately effective at capturing fish, but only when water conditions allowed for sighting fish.

Instream abundance peaked at 2,050 adults in week 45 and declined to 58 fish in week 50 (Table 8). Period-to-period survival rates varied from 0.04 to 1.0 (constrained, Table 8). Two estimates of survival and 5 estimates of recruitment were constrained to yield admissible (realistic) values during the estimation procedure.

Goodness-of-fit tests suggested some potential for capture heterogeneity or handling mortality. Specifically, it appears that fish first captured prior to period 44 and in period 44 were significantly more likely to be seen later in the experiment than fish caught and marked for the first time during period 44. In contrast, fish caught prior to period 45 and in period 45 were significantly less likely to be seen later in the experiment than fish caught and marked for the first time during period 45 (Table 9, component 1). These test results do not indicate a clear pattern in capture heterogeneity or handling mortality.

Nineteen (19.5%) of the sample was captured or recovered in section 1, 56.1% at section 2, 22.9% at section 3, and 1.5% at tidewater (Table 10). In total, 14.3% of the fish inspected for Floy™ tags had either a tag or a secondary mark. The probability of capturing a tagged fish was significantly different in section 1 versus section 2 ($\chi^2 = 15.9$, P < 0.0001) and section 1 versus section 3 ($\chi^2 = 26.4$, P < 0.0001).

Length distributions of adult coho salmon captured in 2005 in Nakwasina River did not appear to be different between capture and
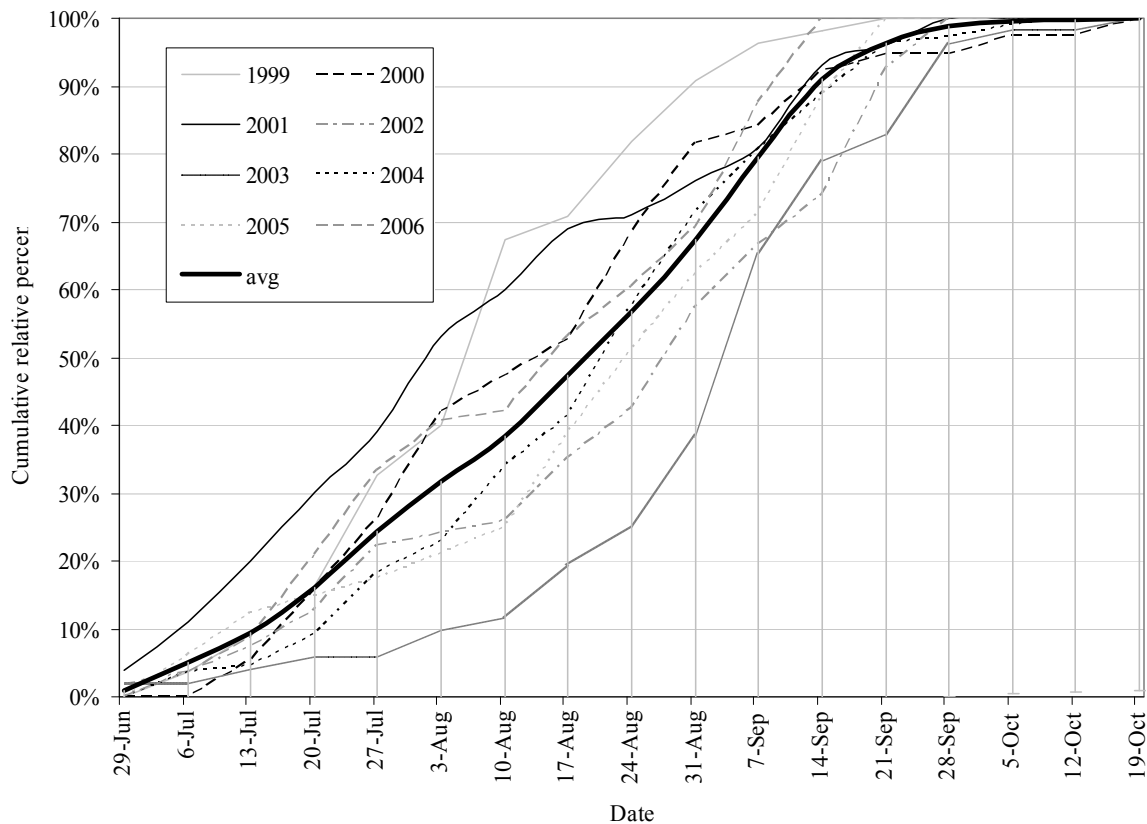
Figure 4.–Cumulative relative percent of Nakwasina River coded wire tag returns by date between 1999 and 2006 in marine sport and commercial fisheries.

recapture or time of capture (Figure 5), but there was a lack of evidence to reject the null hypothesis in some cases (Table 11). The average lengths of female and male coho salmon were 638 mm FL (SE = 1.8) and 621 mm FL (SE = 2.8), respectively. More males than females were caught in sections 1 and 2 ($\chi^2$ = 15.92, P = 0.001, Table 12).

Based on an escapement estimate of 3,539, a coho salmon marine harvest of 1,801 (1,796 plus 2 Yakutat fish, 2 select recoveries and 1 random recovery without quadrant data), and smolt abundance of 47,573, the estimated total run in 2005 was 5,340 (SE = 848) and ocean survival was 11.2% (SE = 2.0%). Total exploitation was estimated to be 33.7% (SE = 5.9%).

## 2006

The estimated spawning escapement of coho salmon in Nakwasina River was 5,698 fish (SE = 741). Coho salmon were marked and recaptured in all 13 weeks of the study (September 5–December 11). Altogether, sampling resulted in 2,139 fish

captures; 1,634 unique adults were captured and examined and 505 were recaptures (Table 7, Appendix A3). No recaptured fish lost its numbered tag as evidenced by the operculum punches. A total of 211 fish were sacrificed for their CWTs or died on capture. Eleven carcasses were sampled. Most adult coho captured in Nakwasina River in 2006 were captured with either the beach seine or gillnet, while 219 were captured with hook-and-line. Hook-and-line gear was moderately effective at capturing fish, but only when water conditions allowed for sighting fish.

Instream abundance peaked at 2,146 adults in week 42 and declined to 34 fish in week 50 (Table 8). Period-to-period survival rates varied from 0.038 to 1.0 (constrained, Table 8). Three estimates of survival and 5 estimates of recruitment were constrained to yield admissible (realistic) values during the estimation procedure.

Goodness-of-fit tests suggested little potential for capture heterogeneity or handling mortality (Table

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Table 7.–Summarized mark–recapture data for Nakwasina River coho salmon, 2005 and 2006. Notation follows that in Seber (1982).

| Week | 2005 | | | | 2006 | | | |
| | Number captured | Number marked caught in *mi* | Losses on capture | Subsequently recaptured | Number captured | Number marked caught in *mi* | Losses on capture | Subsequently recaptured |
|---|---|---|---|---|---|---|---|---|
| 35 | | | | | 1 | | 1 | |
| 36 | | | | | 7 | | 2 | |
| 37 | 4 | | | | 18 | | 6 | |
| 38 | 1 | | 1 | | 18 | | 3 | 1 |
| 39 | 10 | | 4 | 4 | 19 | | 7 | 2 |
| 40 | 39 | | 11 | 20 | 66 | | 12 | 17 |
| 41 | 55 | 3 | 9 | 11 | 104 | 8 | 11 | 15 |
| 42 | 54 | 2 | 14 | 12 | 272 | 10 | 37 | 58 |
| 43 | 134 | 9 | 32 | 24 | 194 | 14 | 23 | 71 |
| 44 | 153 | 23 | 30 | 20 | 229 | 34 | 25 | 91 |
| 45 | 132 | 15 | 23 | 21 | 262 | 69 | 19 | 96 |
| 46 | 173 | 24 | 29 | 29 | 219 | 58 | 17 | 65 |
| 47 | 206 | 51 | 30 | 10 | 304 | 104 | 18 | 63 |
| 48 | | | | | 217 | 108 | 11 | 20 |
| 49 | 54 | 13 | 4 | 2 | 175 | 82 | 17 | 6 |
| 50 | 58 | 13 | 6 | | 34 | 18 | 2 | |
| Total | 1,073 | 155 | 193 | 153 | 2,139 | 505 | 211 | 505 |

9, component 1). Therefore, the potential for bias from capture or survival heterogeneity was small, and the reported estimate is considered reliable for management purposes.

Ten percent (10.4%) of the sample was captured or recovered in section 1, 45.9% at section 2, 41.9% at section 3, and 1.9% at tidewater (Table 10). In total, 23.6% of the fish inspected for Floy™ tags had a tag. The probability of capturing a tagged fish was not significantly different in sections 1 versus section 2 ($\chi^2$ = 0.66, P < 0.414), but was between sections 1 and 2 combined versus section 3 ($\chi^2$ = 162.57, P < 0.000).

Length distributions of adult coho salmon captured in 2006 in Nakwasina River did not appear to be different between capture and recapture or time of capture (Figure 6), but there was a lack of evidence to reject the null hypothesis in some cases (Table 11). The average lengths of female and male coho salmon were 649.8 mm FL (SE = 1.3) and 632 mm FL (SE = 2.16), respectively. The proportions of males and females captured in sections 1, 2, and 3 were not significantly different ($\chi^2$ = 1.76 P =0.415, Table 12), but recapture rates were significantly different ($\chi^2$ = 5.09 P < 0.024, Table 12).

Based on an escapement estimate of 5,698, a coho salmon marine harvest of 1,416 fish, and smolt abundance of 64,164, the estimated total run in 2006 was 7,107 (SE = 767) and ocean survival was 11.1% (SE = 1.3%). Total exploitation was estimated to be 19.8% (SE = 2.7%).

## VISUAL COUNTS

Visual counts were conducted on Nakwasina River on 3 occasions in 2005 and 4 occasions in 2006 (Table 13). In 2005, the peak count was 892 on November 7. In 2006, the peak count was 996 on November 6. Although the peak counts were not bracketed, stream conditions in both 2005 and 2006 precluded an additional count. In subsequent weeks when stream conditions would have allowed an additional count, it was obvious that there were fewer fish. These peak counts represent 25.2% and 17.5% of the estimated escapement respectively.

Table 8.–Jolly-Seber estimates of abundance (N), survival (φ), and recruitment (B) of adult coho salmon at Nakwasina River, 2005 and 2006.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | 2005 | | | |
| Week(s) | Dates | $\hat{N}$ | $SE(\hat{N})$ | $\hat{\phi}$ | $SE(\hat{\phi})$ | $\hat{B}$ | $SE(\hat{B})$ |
| 37–40 | 9/4–10/1 | 713 | 376 | 1.0000 | 0.0000 | - | - |
| 41 | 10/2–10/8 | 697 | 376 | 0.9681 | 0.2739 | 900 | 460 |
| 42 | 10/9–10/15 | 1,566 | 401 | 0.9464 | 0.2571 | - | - |
| 43 | 10/16–10/22 | 1,468 | 293 | 1.0000 | 0.0000 | - | - |
| 44 | 10/23–10/29 | 1,436 | 293 | 0.7709 | 0.1986 | 967 | 571 |
| 45 | 10/30–11/5 | 2,050 | 699 | 0.4943 | 0.1263 | 193 | 280 |
| 46 | 11/6–11/12 | 1,196 | 183 | 0.8071 | 0.2623 | - | - |
| 47 | 11/13–11/19 | 941 | 304 | 0.8090 | 0.6036 | 459 | 450 |
| 49 | 11/20–12/3 | 1,196 | 906 | 0.0400 | 0.0277 | 10 | 17 |
| 50 | 12/4–12/10 | 58 | 7.54 | 0.0000 | 0.0000 | - | - |
| | | | | 2006 | | | |
| Week(s) | Dates | $\hat{N}$ | $SE(\hat{N})$ | $\hat{\phi}$ | $SE(\hat{\phi})$ | $\hat{B}$ | $SE(\hat{B})$ |
| 35–40 | 8/27–10/7 | 1,305 | 416 | 1.0000 | 0.0000 | - | - |
| 41 | 10/8–10/14 | 1,274 | 416 | 0.4310 | 0.0972 | 1,601 | 731 |
| 42 | 10/15–10/21 | 2,146 | 768 | 0.5262 | 0.0742 | 998 | 414 |
| 43 | 10/22–10/28 | 2,107 | 223 | 0.7944 | 0.0904 | - | - |
| 44 | 10/29–11/4 | 1,656 | 170 | 0.8804 | 0.0839 | - | - |
| 45 | 11/5–11/11 | 1,436 | 159 | 1.0000 | 0.0000 | 527 | 146 |
| 46 | 11/12–11/18 | 1,944 | 126 | 0.9100 | 0.1013 | - | - |
| 47 | 11/19–11/25 | 1,754 | 183 | 1.0000 | 0.0000 | - | - |
| 48 | 11/26–12/2 | 1,736 | 183 | 0.4384 | 0.1743 | 93 | 84 |
| 49 | 12/3–12/9 | 849 | 337 | 0.0380 | 0.0152 | 2 | 6 |
| 50 | 12/10–12/16 | 34 | 5.81 | 0.0000 | 0.0000 | - | - |

# DISCUSSION

## SMOLT ABUNDANCE

The smolt-to-adult survival rates of 11.2% and 11.1% in 2005 and 2006 are higher than the 2000–2004 average (9.4%), but still lower than some of the other systems in the region (Table 14). Because of the low average smolt-to-adult survival rate in Nakwasina River in 2000–2002 (8.7%), extra care was taken in springs of 2004–2005 to insure smolt were given an adequate opportunity to recover and smolt naturally. However, survival remained relatively low in 2005–2006, indicating that Nakwasina River coho smolt-to-adult survival rate may tend toward the lower end of the range observed in Southeast Alaska systems.

Condition 1 of an unbiased estimate of smolt abundance required that there was no recruitment to the population between years. Because almost all wild coho salmon return to their natal streams and sampling only occurred in the river, there was probably no appreciable recruitment to the stock between marking and recovery. The presence of stray coho salmon reared at Medvejie hatchery is possible but unlikely given the geographical distance between the 2 sites. Additionally, no coho salmon from Medvejie hatchery have been recovered in Salmon Lake, which is much closer to the hatchery release area.

Vincent-Lang (1993) has shown that coho salmon smolt marked as in this project and handled competently suffer no detectable mortality from the experience, so condition 2 was satisfied. Also, there is no reason to believe that capture rates for adults was influenced by the code on a tag imbedded deep within its cartilage. For these reasons, the differences in recovery rates were most likely due to natural differences in survival rates.

Table 9.–Summary of goodness-of-fit tests for homogeneous capture/survival probabilities by tag group in 2005 and 2006. Overall χ2 are the sum of the individual test statistics.

| | 2005 | | | | | |
|---|---|---|---|---|---|---|
| | Component 1[a] | | | Component 2[b] | | |
| Period | $\chi^2$ τατσ | df | P-value | $\chi^2$ τατσ | df | P-value |
| 42 | 1.009 | 1 | 0.315 | -- | 0 | -- |
| 43 | 2.309 | 1 | 0.129 | 3.273 | 1 | 0.070 |
| 44 | 3.915 | 1 | 0.048 | 0.101 | 1 | 0.751 |
| 45 | 5.168 | 1 | 0.023 | -- | 0 | -- |
| 46 | 3.441 | 1 | 0.064 | -- | 0 | -- |
| 47 | 0.348 | 1 | 0.555 | 0.117 | 1 | 0.732 |
| 49 | 0.094 | 1 | 0.342 | 0.069 | 1 | 0.393 |
| 50 | 0.732 | 1 | 0.392 | -- | 0 | -- |
| Overall | 17.826 | 8 | 0.023 | 3.560 | 4 | 0.469 |
| | 2006 | | | | | |
| | Component 1[a] | | | Component 2[b] | | |
| Period | $\chi^2$ τατσ | df | P-value | $\chi^2$ τατσ | df | P-value |
| 41 | 0.085 | 1 | 0.770 | 1.225 | 1 | 0.269 |
| 42 | 0.159 | 1 | 0.690 | 0.581 | 1 | 0.446 |
| 43 | 1.053 | 1 | 0.305 | 0.043 | 1 | 0.836 |
| 44 | 0.480 | 1 | 0.488 | 0.130 | 1 | 0.719 |
| 45 | 0.134 | 1 | 0.714 | 0.005 | 1 | 0.942 |
| 46 | 1.234 | 1 | 0.267 | 0.067 | 1 | 0.796 |
| 47 | 0.385 | 1 | 0.535 | 0.874 | 1 | 0.350 |
| 49 | 0.052 | 1 | 0.819 | 0.392 | 1 | 0.531 |
| 50 | 0.004 | 1 | 0.950 | -- | 0 | -- |
| Overall | 3.586 | 9 | 0.937 | 3.316 | 8 | 0.913 |

[a]  Test for short-term mortality per Robson (1969).

[b]  Test for heterogenous survival probabilities per Pollock et al. (1990).

Table 10.–Results of χ2 tests for differences in tagged rate between river sections for coho salmon in the Nakwasina River, 2005 and 2006.

| | 2005 | | | |
|---|---|---|---|---|
| Section | Untagged | Tagged | Total | % of total captures by section |
| 1 | 156 | 53 | 209 | 19.48% |
| 2 | 521 | 81 | 602 | 56.10% |
| 3 | 227 | 19 | 246 | 22.93% |
| Tidewater | 16 | | 16 | 1.49% |
| Total | 920 | 153 | 1,073 | |
| Sections 1–3 | χ 2= | 29.56 | P< | 0.0000 |
| | 2006 | | | |
| Section | Untagged | Tagged | Total | % of total captures by section |
| 1 | 151 | 71 | 222 | 10.4% |
| 2 | 639 | 342 | 981 | 45.9% |
| 3 | 804 | 92 | 896 | 41.9% |
| Tidewater | 40 | | 40 | 1.87% |
| Total | 1,634 | 505 | 2,139 | |
| Sections 1–3 | χ 2= | 163.57 | P< | 0.0000 |

It is unlikely that smolt regenerated the clipped adipose fin that identified the fish as containing a tag, so it is likely that condition 3 was satisfied. In conjunction with tag retention and overnight mortality tests, adipose finclips on smolt were examined. All smolt examined appeared to have good finclips. Also, all adult coho examined had well defined or a complete absence of an adipose fin.

Although the assumption that complete mixing occurred cannot be tested, coho salmon most likely mixed within or across stocks during their extended time (14 months) at sea. In Nakwasina River catches, the fraction of adult coho salmon with marks (missing an adipose fin) did not vary significantly over time in either 2005 (χ2 = 1.67, P = 0.434) or 2006 (χ2 = 3.087, P = 0.215; Table 15).

Figure 5.–Cumulative length frequency distributions to test for differences in lengths of captured coho by sex, location, capture or recapture, gear and time, 2005.

Table 11.–Results of Kolmogorov-Smirnov tests for differences between cumulative length frequencies for adult coho salmon in the Nakwasina River, 2005 and 2006.

| | | | 2005 | | | |
|---|---|---|---|---|---|---|
| Component 1 | n | | Component 2 | n | $D_i$ | P-value |
| Males | 548 | vs. | Females | 371 | 0.17 | <0.000 |
| 9 Sep–20 Oct | 283 | vs. | 25 Oct–6 Dec | 637 | 0.15 | <0.000 |
| Hook and Line | 90 | vs. | Seine | 529 | 0.13 | 0.113 |
| Tangle Net | 299 | vs. | Seine | 529 | 0.08 | 0.166 |
| Original Capture | 920 | vs. | Recapture | 140 | 0.05 | 0.865 |
| Section 1 | 156 | vs. | Section 3 | 227 | 0.07 | 0.765 |
| Section 1 | 156 | vs. | Section 2 | 521 | 0.08 | 0.354 |
| | | | 2006 | | | |
| Component 1 | n | | Component 2 | n | $D_i$ | P-value |
| Males | 896 | vs. | Females | 735 | 0.16 | <0.000 |
| 9 Sep–17 Oct | 217 | vs. | 26 Oct–6 Dec | 599 | 0.08 | 0.393 |
| Hook and Line | 219 | vs. | Seine | 1,410 | 0.08 | 0.587 |
| Original Capture | 816 | vs. | Recapture | 252 | 0.05 | 0.769 |
| Section 1 | 150 | vs. | Section 3 | 802 | 0.09 | 0.303 |
| Section 1 | 150 | vs. | Section 2 | 320 | 0.05 | 0.929 |

Table 12.–Differences in sex composition of coho salmon between capture type, gear, and section of Nakwasina River, 2005 and 2006.

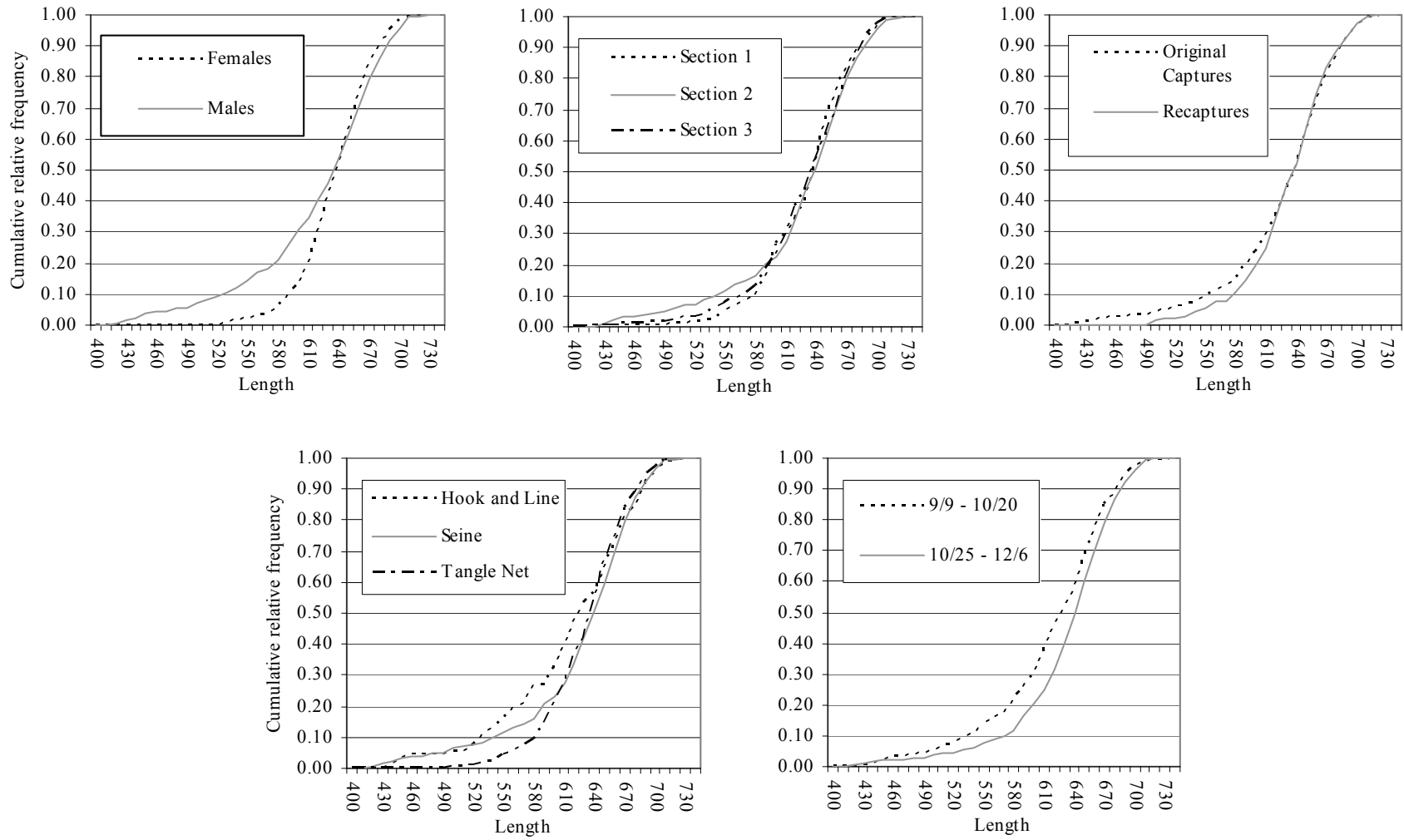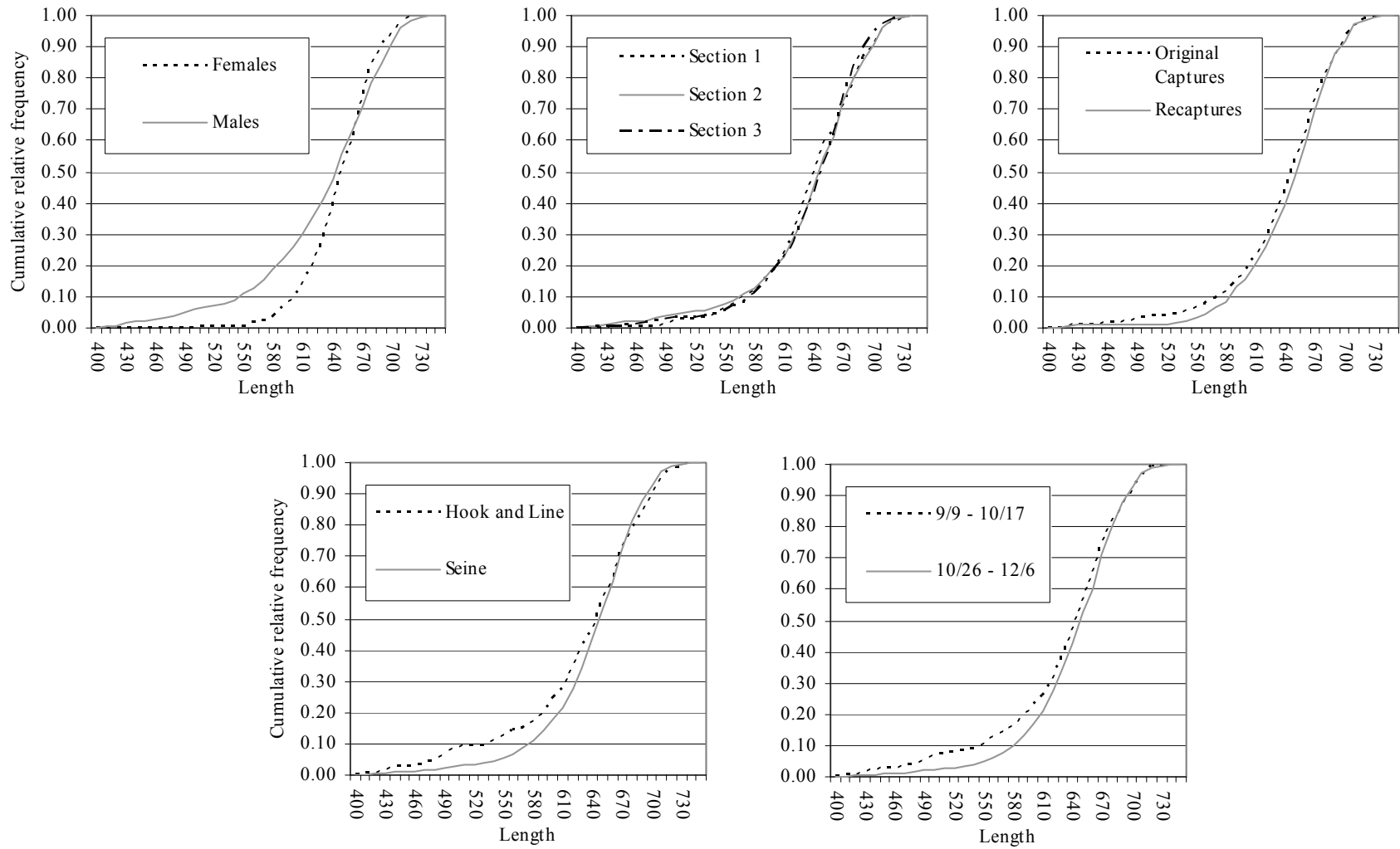| | | | 2005 | | |
|---|---|---|---|---|---|
| Capture | Females | Males | % Males | $\chi^2$ | P-value |
| Captured | 371 | 548 | 59.63% | 0.16 | 0.686 |
| Recaptured | 54 | 86 | 61.43% | | |
| Gear type | | | | | |
| Hook and line | 36 | 54 | 60.00% | 5.36 | 0.021 |
| Seine/tangle net | 651 | 586 | 47.37% | | |
| Section | | | | | |
| 1 | 83 | 125 | 60.10% | 15.92 | 0.001 |
| 2 | 217 | 385 | 63.95% | | |
| 3 | 124 | 121 | 49.39% | | |
| Tidewater | 5 | 11 | 68.75% | | |
| | | | 2006 | | |
| Capture | Females | Males | % Males | $\chi^2$ | P-value |
| Captured | 736 | 897 | 54.93% | 5.09 | 0.024 |
| Recaptured | 198 | 305 | 60.64% | | |
| Gear type | | | | | |
| Hook and line | 112 | 126 | 52.94% | 1.18 | 0.278 |
| Seine/tangle net | 822 | 1,074 | 56.65% | | |
| Location | | | | | |
| 1 | 96 | 126 | 56.76% | 1.76 | 0.415 |
| 2 | 412 | 568 | 57.96% | | |
| 3 | 403 | 491 | 54.92% | | |
| Tidewater | 23 | 17 | 42.50% | | |

Figure 6.–Cumulative length frequency distributions to test for differences in lengths of captured coho by sex, location, capture or recapture, gear and time, 2006.

Smolt-to-adult survival rates for smolt tagged in both 2004 and 2005 in the mainstem of Nakwasina River and those tagged in Bridge Creek were not significantly different. No significant differences in smolt-to-adult survival were detected between small and large tagging groups for smolt tagged in 2004 and 2005. Based on these results, we concluded that either S2 or S3 was satisfied and a Petersen-type model was appropriate for estimating abundance of 2004 and 2005 coho smolts from the Nakwasina River.

## SPAWNING ESCAPEMENTS IN 2005 AND 2006

During both 2005 and 2006 experiments to estimate spawning escapement, tag loss was low (<1%) and sampling rates were high. Marking did not appear to affect the behavior or movement of fish, as marked fish were observed spawning with or near unmarked fish throughout the study. In 2006, assumptions of the JS experiment were met, and the JS model fit the data. In 2005, diagnostic testing for handling mortality and/or heterogeneity in probability of capture or survival indicated some potential for these problems. The significant test statistics occurred for adjacent sampling periods, and the direction of potential sampling bias was not consistent between these periods. No significant results were detected during later sampling periods where sample sizes for the tests were slightly larger. As no persistent pattern was apparent, it is difficult to draw clear conclusions about the potential for bias resulting from possible sampling problems indicated by the diagnostic tests.

A higher rate of recapture was observed for males than females in 2006. This may have been due to error in determining the sex of fish early in the run. Because the secondary maturation characteristics had not fully developed earlier in the run, it is possible that some fish were misidentified as females. Similar tests from previous years have yielded inconsistent results, with no difference detected between male and female recapture rates in 2000, 2002, and 2005, but a significantly higher apparent recapture rate for females in 2001, and a significantly higher rate for males in 2003 (Brookover et al. 2003; Tydingco 2003, 2005a-b). The lack of pattern

**Table 13.**–2005 and 2006 stream counts including number of coho counted, date, survey conditions, and percentage of total escapement estimate represented by daily count.

| Date | Count | Conditions | % of total escapement |
|---|---|---|---|
| 10/7/2005 | 440 | Visibility normal, tide low, water normal | 12.4% |
| 10/31/2005 | 763 | Visibility normal, tide low, water normal | 21.6% |
| 11/7/2005[a] | 892 | Visibility normal, tide low, water normal | 25.2% |
| 10/11/2006 | 508 | Visibility normal, tide high, water normal | 8.9% |
| 10/27/2006 | 605 | Visibility poor, tide low, water normal | 10.6% |
| 11/2/2006 | 871 | Visibility poor, tide low, water normal | 15.3% |
| 11/6/2006[a] | 996 | Visibility poor, tide high, water normal | 17.5% |

[a] Peak count

**Table 14.**–Smolt-to-adult survival rate for coho indicator streams around Southeast Alaska 2000–2006.

| | Return year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Stream | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | Average |
| Auke Creek | 18.5 | 28.3 | 26.8 | 25 | 20.7 | 16 | 17.1 | 21.8 |
| Berners River | 12.1 | 11.9 | 19 | 19.1 | 17.7 | 8.4 | 12.8 | 14.4 |
| Taku River | 6.3 | 8.8 | 11.1 | 8.9 | 8.6 | 8.1 | 9.8 | 8.8 |
| Ford Arm | 12.8 | 8.2 | 14.7 | 17 | 11.9 | 8.1 | 9.9 | 11.8 |
| Hugh Smith Lake | 6.6 | 13.5 | 14.5 | 13.7 | 10.4 | 9.1 | 6.7 | 10.6 |
| Unuk River | 3.8 | 11.4 | 9.3 | | | | | 8.2 |
| Nakwasina River | 6.8 | 9.5 | 9.8 | 11.9 | 9.9 | 11.2 | 11.1 | 10.0 |
| Slippery Creek | | | 17.5 | | | | | |
| Chuck Creek | | | | | 9.4 | | | |
| Average | 9.6 | 13.1 | 15.3 | 15.9 | 12.7 | 10.2 | 11.2 | 12.2 |

Table 15.–Proportion of recovered Nakwasina River adult coho observed with and without adipose finclips, 2005 and 2006.

| | 2005 | | | | 2006 | | |
|---|---|---|---|---|---|---|---|
| Date | Observed without clip | Observed with clip | Tagged portion | Date | Observed without clip | Observed with clip | Tagged portion |
| 9/9/2005 | 4 | | | 8/30/2006 | | 1 | |
| 9/13/2005 | | 1 | | 9/5/2006 | 7 | | |
| 9/20/2005 | 2 | 2 | 0.50 | 9/11/2006 | 12 | | |
| 9/23/2005 | 5 | 1 | 0.17 | 9/15/2006 | 3 | 3 | 0.50 |
| 9/30/2005 | 23 | 5 | 0.18 | 9/18/2006 | 16 | 2 | 0.11 |
| 10/1/2005 | 8 | 3 | 0.27 | 9/26/2006 | 15 | 4 | 0.21 |
| 10/3/2005 | 43 | 5 | 0.10 | 10/1/2006 | 28 | 7 | 0.20 |
| 10/8/2005 | 1 | 3 | 0.75 | 10/2/2006 | 18 | 5 | 0.22 |
| 10/12/2005 | 3 | 3 | 0.50 | 10/3/2006 | 8 | | |
| 10/14/2005 | 40 | 6 | 0.13 | 10/9/2006 | 65 | 12 | 0.16 |
| 10/17/2005 | 57 | 19 | 0.25 | 10/10/2006 | 15 | 3 | 0.17 |
| 10/20/2005 | 36 | 13 | 0.27 | 10/12/2006 | | 1 | |
| 10/24/2005 | 18 | 6 | 0.25 | 10/16/2006 | 37 | 9 | 0.20 |
| 10/25/2005 | 39 | 14 | 0.26 | 10/17/2006 | 129 | 33 | 0.20 |
| 10/27/2005 | 42 | 10 | 0.19 | 10/19/2006 | 18 | 6 | 0.25 |
| 10/28/2005 | | 1 | | 10/20/2006 | 25 | 5 | 0.17 |
| 11/1/2005 | 92 | 22 | 0.19 | 10/26/2006 | 12 | 7 | 0.37 |
| 11/2/2005 | 2 | 1 | 0.33 | 10/27/2006 | 38 | 12 | 0.24 |
| 11/8/2005 | 46 | 14 | 0.23 | 10/28/2006 | 92 | 19 | 0.17 |
| 11/9/2005 | 74 | 15 | 0.17 | 11/2/2006 | 58 | 24 | 0.29 |
| 11/14/2005 | 79 | 16 | 0.17 | 11/3/2006 | 87 | 26 | 0.23 |
| 11/15/2005 | 46 | 14 | 0.23 | 11/7/2006 | 141 | 36 | 0.20 |
| 11/28/2005 | 11 | 1 | 0.08 | 11/8/2006 | 11 | 5 | 0.31 |
| 11/29/2005 | 12 | 4 | 0.25 | 11/14/2006 | 128 | 33 | 0.20 |
| 11/30/2005 | 11 | 2 | 0.15 | 11/21/2006 | 163 | 37 | 0.19 |
| 12/5/2005 | 13 | 1 | 0.07 | 11/28/2006 | 90 | 19 | 0.17 |
| 12/6/2005 | 24 | 7 | 0.23 | 12/4/2006 | 25 | 5 | 0.17 |
| Total | 731 | 189 | 0.205 | 12/5/2006 | 50 | 13 | 0.21 |
| 9 Sep–8 Oct | 86 | 20 | | 12/11/2006 | 13 | 3 | 0.19 |
| 12 Oct–2 Nov | 329 | 95 | | Total | 1,304 | 330 | 0.202 |
| 8 Nov–6 Dec | 316 | 74 | | 30 Aug–10 Oct | 187 | 37 | |
| | $\chi^2 =$ | 1.67 | | 12 Oct–2 Nov | 409 | 116 | |
| | P = | 0.434 | | 3 Nov–11 Dec | 708 | 177 | |
| | | | | | $\chi^2 =$ | 3.08 | |
| | | | | | P = | 0.215 | |

across years suggests that apparent differences are more likely the result of misclassification than in behavioral differences between males and females that affect probability of recapture. If, during 2006, the probability of capture for females was lower than that for males throughout the experiment, the abundance estimate is biased low.

The fact that the JS estimations were constrained to yield admissible values does not necessarily indicate that violation of some of the assumptions occurred and that the estimation model was inappropriate (Schwarz et al. 1993). However, assumptions that all fish have the same survival rate and that all fish have the same probability of capture during each event are not likely to be satisfied in a field experiment such as this one, so potential for bias in the abundance estimate needs to be considered. Differences were found between the fractions of fish carrying marks in upriver and downriver locations (Table 10), indicating that marked and unmarked fish did not mix completely between sampling events. Lack of complete mixing between events can only be mitigated by application of uniform sampling effort across the

study area during each event, ensuring similar probabilities of capture for all fish. While it is unlikely that equal capture probabilities can be uniformly achieved, field efforts to sample proportional to fish abundance across the study area are intended to minimize the potential for bias. It is not expected that the survival rate is uniform across all fish in the experiment between sampling events. "Older" fish are expected to have a lower survival rate between events, particularly later in this experiment. While Seber (1982), as cited by Sykes and Botsford (1986), suggests that JS estimates should be relatively unbiased if mark status and mortality are not correlated, Schwarz et al. (1993) demonstrated with simulation that declines in survival of 20% between successive sampling periods after new fish enter the study area can result in overestimates of abundance on the order of one standard error of the point estimate. However, if "older" fish are also more susceptible to capture due to declining condition, a negative bias can result that may nearly cancel the positive bias resulting from the survival heterogeneity. While it is expected that fish in this experiment tended to experience lower survival later in their tenure in the study area, it is not likely as well correlated or severe as that simulated by Schwarz et al. (1993). If the escapement estimate is biased due to differential mortality, it is biased high and the magnitude of the bias is within one standard error of the estimate.

Although some fish do temporarily emigrate and re-immigrate after being tagged, no data exists to indicate a problem due to fish from other systems temporarily entering the system, being tagged, and then permanently emigrating. Some fish may temporarily emigrate from the study area due to stress associated with handling and tagging and later re-immigrate into the study area. In 2001, a Floy™ tagged fish with fresh herring in its belly was returned by a fisherman that captured the fish in Nakwasina River. This indicates that some fish do temporarily emigrate and re-immigrate after being tagged. The temporary lack of closure is not likely a significant source of bias. Of 140 first recaptures of marked fish in 2005, 41% occurred during the sampling event immediately after the tagging event and 58% occurred during either the first or second event immediately after tagging.

In 2005 and 2006, 10 and 27 fish were tagged at tidewater respectively. Of these, 6 and 16 were recovered. These recovery rates are higher than sections 2 and 3 (Table 16) and therefore indicate that problems associated with tagging mortality near the saltwater/freshwater interface (Vincent-Lang 1993) were not present during this study.

## VISUAL COUNTS

Nakwasina River is similar to other clearwater streams in the area, and the relationship between the peak observer count and the total escapement is similar to that found in Steep Creek near Juneau, Alaska (21% in Steep Creek and 20% in Nakwasina River: Jones III and McPherson 1997; McPherson et al. 1996). The ability to count spawning salmon depends on many factors, including the observer, weather, water clarity, canopy cover, pool-to-riffle ratio, the density of fish, the amount of undercut banks, and the ecology, behavior, size, and color of salmon (Jones III 1995).

## HARVEST SAMPLING

To assess the adequacy of sampling rates in the purse seine and gillnet fisheries, troll harvests within Southeast Alaska where Nakwasina River coho salmon recovery occurred were examined (Table 17). The sampling rates in 2005 for troll fisheries in the Northwest Quadrant ranged from 6% (District 105) to 22% (Districts 116). In 2006 sampling rates ranged between 18% in District 105 and 30% in District 189. Because not all fisheries were sampled, it is likely that Nakwasina River coho salmon harvest was undetected in some fisheries, which would result in an underestimated total marine harvest. On average, 50% of the harvest of CWT-marked coho between 1999 and 2006 occurs by August 20, and 90% are recovered by September 14.

Nakwasina River coho appear to have a later run timing than some of the other streams in the Sitka area. Peak stream counts generally occur in late October or early November in the Nakwasina River, up to a month later than the other 5 index streams in the Sitka Area (Table 2). Additionally tag recoveries in marine fisheries occur later than Salmon Lake (Figure 7) by approximately a month. Anecdotal information suggests that Katlian River, near Sitka, exhibits a similar run

Table 16.–Numbers of coho salmon recaptured by section of original tagging and section of recapture in Nakwasina River, 2005 and 2006.

| | 2005 | | | |
|---|---|---|---|---|
| | Original tag section | | | |
| Section of recapture | Upstream 1 | Middle section 2 | Lower section 3 | Tidewater |
| Upstream 1 | 12 | 28 | 11 | 2 |
| Middle section 2 | | 51 | 26 | 4 |
| Lower section 3 | | 10 | 9 | |
| Totals | 12 | 89 | 46 | 6 |
| Total number of fish tagged | 124 | 418 | 175 | 10 |
| Proportion recovered | 0.10 | 0.21 | 0.26 | 0.60 |

| | 2006 | | | |
|---|---|---|---|---|
| | Original tag section | | | |
| Section of recapture | Upstream 1 | Middle section 2 | Lower section 3 | Tidewater |
| Upstream 1 | 14 | 21 | 32 | 2 |
| Middle section 2 | 1 | 142 | 189 | 9 |
| Lower section 3 | | 19 | 66 | 5 |
| Totals | 15 | 182 | 287 | 16 |
| Total number of fish tagged | 125 | 562 | 711 | 27 |
| Proportion recovered | 0.12 | 0.32 | 0.40 | 0.59 |

timing to the Nakwasina River, but most streams in the area follow a return pattern similar to the other 5 index streams.

Table 17.–Numbers of fish harvested in troll fisheries and sampled for coded wire tags in districts where Nakwasina River coho salmon were recovered, 2005 and 2006.

| | 2005 | | |
|---|---|---|---|
| District | Fish harvested | Fish sampled | Proportion sampled |
| 105 | 19,450 | 1,246 | 0.06 |
| 113 | 682,744 | 156,279 | 0.19 |
| 114 | 147,118 | 37,123 | 0.20 |
| 116 | 9,158 | 2,590 | 0.22 |
| 154 | 3,820 | 890 | 0.19 |
| 181 | 797 | 374 | 0.32 |
| 189 | 23,597 | 6,687 | 0.22 |
| | 886,684 | 205,189 | 0.19 |

| | 2006 | | |
|---|---|---|---|
| District | Fish harvested | Fish sampled | Proportion sampled |
| 105 | 9,136 | 2,071 | 0.18 |
| 109 | 46,366 | 13,967 | 0.23 |
| 112 | 7,144 | 1,032 | 0.13 |
| 113 | 309,988 | 74,272 | 0.19 |
| 114 | 37,196 | 6,444 | 0.15 |
| 116 | 52,686 | 18,146 | 0.26 |
| 189 | 8,923 | 3,788 | 0.30 |
| | 471,439 | 119,720 | 0.20 |

## EXPANSION FACTOR

As a tool for estimating escapement without the use of a mark–recapture experiment, an expansion factor was developed for the Nakwasina River. Peak counts were compared to escapement for all years that peak counts and escapement were available, except 2004 when a peak count wasn't available due to poor water conditions. During the 6 years compared, estimated escapements ranged between 2,000 and 5,698 fish (Table 1, Figure 8). The resulting expansion factor (as estimated according to procedures in Appendix A4) was 4.588 (SE = 0.266).

# RECOMMENDATIONS

## CONTINUATION OF PROJECT

This project should continue for the estimation of escapement, harvest, smolt abundance, survival, and exploitation. The long-term relationship between exploitation and abundance should be monitored. Stock information from the Nakwasina River represents the most complete coho data set in the Sitka area and is the only non-lake wild stock in the outside waters of Northern Southeast Alaska with this information. Trends in abundance, survival, and exploitation may only be detected in a river with a long-term data set.
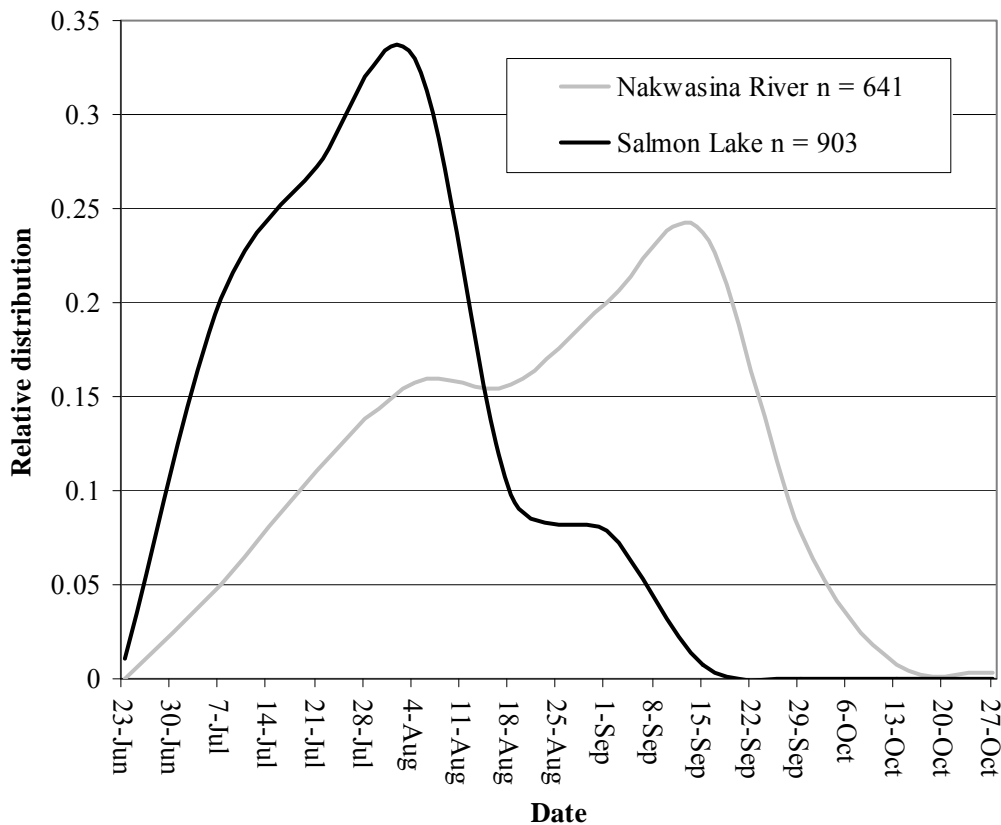
Figure 7.–Relative distribution of coded wire tag recoveries in marine fisheries by date in the Nakwasina River and Salmon Lake between 1988 and 2006.

## DEVELOPMENT OF ADDITIONAL EXPANSION FACTORS

As tools for estimating abundance, the development of additional expansion factors in other streams may provide the opportunity to estimate trends in abundance and the refinement of escapement goals. Because coho salmon in Southeast Alaska frequently exhibit prolonged run timing during the fall and the return timing is often correlated with high water events, estimating escapement can be problematic. The use of open-population mark–recapture experiments may be the only way to successfully estimate abundance in these conditions. Currently, peak counts in the Sitka area are only useful as an index of abundance, but it is unknown how these counts relate to actual escapements. Comparing peak stream counts on other index systems to an estimated escapement would provide a useful tool for not only predicting escapement when only a

stream count is possible, it would also allow the estimation of escapement for prior years. This may provide adequate information for the development of refined escapement goals.

## TAGGING

In future tagging events, extra care should be taken to ensure that any potential effects of tagging are minimized. Recommendations for future tagging include: 1) releasing smolt in side tributaries with extensive available rearing habitat as opposed to mainstem areas with higher velocities; 2) minimizing transport distances by centralizing the tagging and holding site; 3) returning tagged smolt to locations near their capture site; 4) tagging and sampling all fish within 48 hours of capture to ensure fish are not held for periods greater than 72 hours, including overnight mortality testing; and 5) estimating the true contribution and survival of Bridge Creek smolt in the Nakwasina adult escapement. This
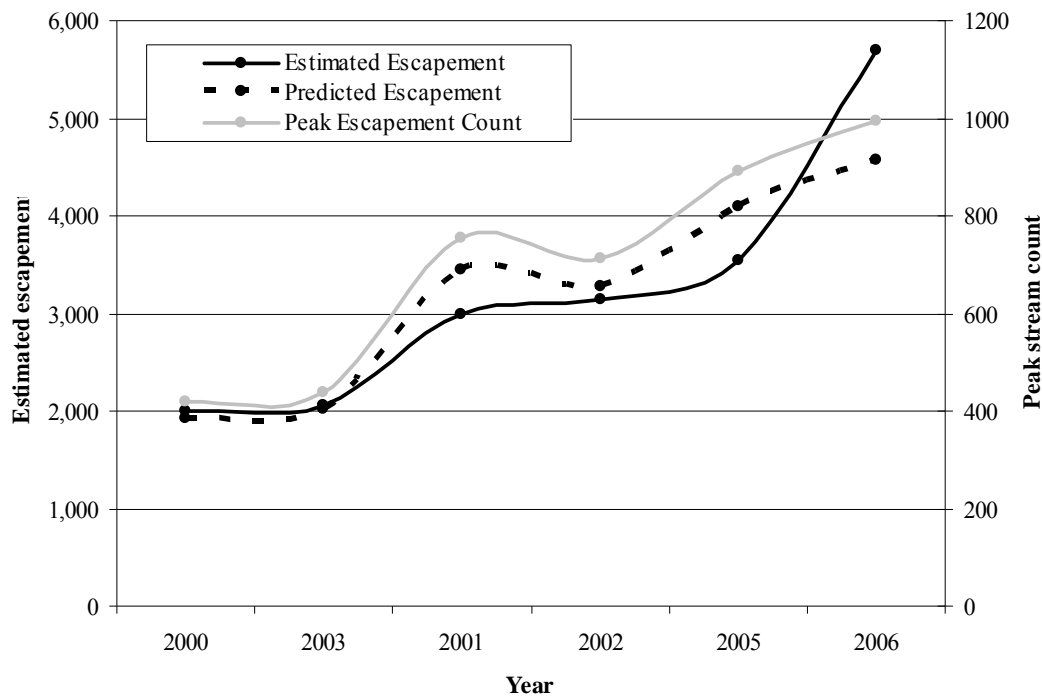
Figure 8.–Estimated escapement, peak counts, and predicted escapement at Nakwasina River, 2000–2006.

may be done by installing a weir on Bridge Creek through the smolting migration and either counting each fish that smolts through the weir or conducting a mark–recapture experiment to estimate the number of smolt in Bridge Creek prior to the smolting migration.

## ACKNOWLEDGEMENTS

## REFERENCES CITED

Arnason, A. N., and C. J. Schwarz. 1995. POPAN-4: enhancements to a system for the analysis of mark-recapture data from open populations. Journal of Applied Statistics, 22:785-800.

Beers, D. E. 1999. Production of coho salmon from Slippery Creek, 1997-1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-46, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-46.pdf

Beers, D. E. 2003. Production of coho salmon from Slippery Creek, 2000-2001. Alaska Department of Fish and Game, Fishery Data Series No. 03-08, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds03-08.pdf

# REFERENCES CITED (Continued)

Bernard, D. R., and J. E. Clark. 1996. Estimating salmon harvest based on return of coded-wire tags. Canadian Journal of Fisheries and Aquatic Sciences 53:2323-2332.

Brookover, T. E., P. A. Hansen, and R. D. Harding. 1999. Population status of summer resident cutthroat trout at Sitkoh Lake, Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 99-30, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-30.pdf

Brookover, T. E., P. A. Hansen, and T. A. Tydingco. 2000. Population status of brook trout at Green Lake, Southeast Alaska, 1999. Alaska Department of Fish and Game, Fishery Data Series No. 00-23, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds00-23.pdf

Brookover, T. E., P. A. Hansen, and T. A. Tydingco. 2003. Smolt production, adult harvest, and spawning escapement of coho salmon from the Nakwasina River in Southeast Alaska, 1999-2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-25, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds03-25.pdf

Clark, J. E., and D. R. Bernard. 1987. A compound multivariate binomial-hypergeometric distribution describing coded microwire tag recovery from commercial salmon catches in Southeastern Alaska. Alaska Department of Fish and Game, Informational Leaflet No. 261, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/afrbil.261.pdf

Cochran, W. G. 1977. Sampling techniques, 3rd edition. John Wiley and Sons, New York.

Conover, W. J. 1980. Practical nonparametric statistics, 2nd edition. John Wiley and Sons, New York.

Efron, B., and R. J. Tibshirani. 1993. An introduction to the bootstrap. Chapman and Hall, New York.

Howe, A. L., G. Fidler, A. E. Bingham, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-32, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds96-32.pdf

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-24, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds95-24.pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001a. Revised Edition. Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-29 (revised), Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds97-29(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001b. Revised Edition. Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-25 (revised), Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds98-25(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Revised Edition. Participation, catch, and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-41 (revised), Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-41(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001d. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-08, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds01-08.pdf

Hubartt, D. J., M. Jaenicke, and A. E. Bingham. 2002. Harvest estimates for selected marine sport fisheries in Southeast Alaska during 2001. Alaska Department of Fish and Game, Fishery Data Series No. 02-30, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds02-30.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2007. Participation, catch, and harvest in Alaska sport fisheries during 2004. Alaska Department of Fish and Game, Fishery Data Series No. 07-40, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds07-40.pdf

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2004. Participation, catch, and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series No. 04-11, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds04-11.pdf

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006a. Participation, catch, and harvest in Alaska sport fisheries during 2002. Alaska Department of Fish and Game, Fishery Data Series No. 06-34, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fds06-34.pdf

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006b. Participation, catch, and harvest in Alaska sport fisheries during 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-44, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fds06-44.pdf

Jones III, E. L. 1995. Observer variability and bias in estimation of Southeast Alaska pink salmon escapement. Master's thesis. University of Alaska, Fairbanks.

Jones III, E. L., and S. A. McPherson. 1997. Relationship between observer counts and abundance of coho salmon in Steep Creek, Northern Southeast Alaska in 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-25, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds97-25.pdf

Jones III, E. L., S. A. McPherson, and A. B. Holm. 1999. Production of coho salmon from the Unuk River, 1997-1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-43, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-43.pdf

Jones III, E. L., J. A. Weller, and A. B. Holm. 2001. Production of coho salmon from the Unuk River, 1999-2000. Alaska Department of Fish and Game, Fishery Data Series No. 01-14, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds01-14.pdf

Koerner, J. F. 1977. The use of the coded wire tag injector under remote field conditions. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 172, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/afrbil.172.pdf

Magnus, D. L., D. Brandenburger, K. F. Crabtree, K. A. Pahlke, and S. A. McPherson. 2006. Juvenile salmon capture and coded wire tagging manual. Alaska Department of Fish and Game, Special Publication No. 06-31, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/sp06-31.pdf

McCurdy, S. J. 2006. Production of coho salmon from the 2004 smolt emigration from Chuck Creek in Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 06-58, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-58.pdf

McPherson, S. A., B. J. Glynn, and E. L. Jones III. 1996. A mark-recapture experiment to estimate the escapement of coho salmon in Steep Creek, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 96-31, Anchorage http://www.sf.adfg.state.ak.us/FedAidPDFs/fds96-31.pdf

Mills, M. J. 1985. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1984-1985, Project F-9-17, 26 (SW-I-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/FREDf-9-17(26)SW-I-A.pdf

Mills, M. J. 1986. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1985-1986, Project F-10-1, 27 (RT-2), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/FREDf-10-1(27)RT-2.pdf

# REFERENCES CITED (Continued)

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report, 1986. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds-002.pdf

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report, 1987. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds-052.pdf

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report, 1988. Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds-122.pdf

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds90-44.pdf

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds91-58.pdf

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds92-40.pdf

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds93-42.pdf

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds94-28.pdf

Mood, A. M., F. A. Graybill, and D. C. Boes. 1974. Introduction to the theory of statistics, 3rd edition. McGraw-Hill Book Co., New York.

Mosher, K. H. 1968. Photographic atlas of sockeye salmon scales. U.S. Fish and Wildlife Service, Fishery Bulletin 67:243-280.

Neter, J., W. Wasserman, and M. H. Kutner. 1990. Applied linear statistical models, 3rd edition. Irwin Publishing Company. Homewood, IL.

Oliver, G. T. *Unpublished*. Alaska Department of Fish and Game coded wire tag sampling program, detailed sampling instructions. 2002. Division of Commercial Fisheries, Southeast Alaska, Juneau.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for mark-recapture experiments. Wildlife Monograph 107.

Robson, D. S. 1969. Mark-recapture methods of population estimation. Pages 120-140 [*in*] N. L. Johnson and H. Smith, Jr., editors, New developments in survey sampling. John Wiley and Sons, New York.

Scarnecchia, D. L. 1979. Variation of scale characteristics of coho salmon with sampling location on the body. Progressive Fish Culturist 41(3):132-135.

Schmidt, A. E. 1996. Interception of wild Salmon Lake coho salmon by hatchery supported fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 96-26, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds96-26.pdf

Schwarz, C. J., and A. N. Arnason. 1996. A general methodology for the analysis of capture-recapture experiments in open populations. Biometrics 52, 860-873.

Schwarz, C. J., R. J. Bailey, J. Irvine, and F. C. Dalziel. 1993. Estimating salmon escapement using capture-recapture methods. Canadian J. Fisheries and Aquatic Sciences 50, 1181-1197.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, 2nd edition. Griffin and Company, Ltd. London.

Shaul, L., and K. Crabtree. 1998. Harvests, escapements, migratory patterns, smolt migrations, and survival of coho salmon in Southeast Alaska based on coded wire tagging, 1994-1996. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 1J98-02, Juneau.

# REFERENCES CITED (Continued)

Sykes, S. D., and L. W. Botsford. 1986. Chinook salmon, *Oncorhynchus tshawytscha,* spawning escapement based on multiple mark-recapture of carcasses. Fishery Bulletin 84:261–270.

Tydingco, T. 2003. Smolt production, adult harvest, and spawning escapement of coho salmon from the Nakwasina River in Southeast Alaska, 2000-2001. Alaska Department of Fish and Game, Fishery Data Series No. 03-19, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds03-19.pdf

Tydingco, T. A. 2005a. Smolt production, adult harvest, and spawning escapement of coho salmon from Nakwasina River in Southeast Alaska, 2002-2003. Alaska Department of Fish and Game, Fishery Data Series No. 05-26, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/Fds05-26.pdf

Tydingco, T. A. 2005b. Smolt production, adult harvest, and spawning escapement of coho salmon from the Nakwasina River in Southeast Alaska, 2001-2002. Alaska Department of Fish and Game, Fishery Data Series No. 05-04, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds05-04.pdf

Tydingco, T. A. 2006. Smolt production, adult harvest, and spawning escapement of coho salmon from Nakwasina River in Southeast Alaska, 2003-2004. Alaska Department of Fish and Game, Fishery Data Series No. 06-66, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-66.pdf

Tydingco, T. A., R. E. Chadwick, S. Reifenstuhl, J. Lorrigan, T. Suminski, and D. Reed. 2006. Stock assessment of Salmon Lake sockeye and coho salmon, 2001-2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-35, Anchorage.http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-35.pdf

Tydingco, T. A., R. E. Chadwick, S. Reifenstuhl, T. Suminski, and D. Reed. 2008. Stock assessment of Salmon Lake coho salmon, 2004–2005. Alaska Department of Fish and Game, Fishery Data Series No. 08-27, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fds08-27.pdf

Vincent-Lang, D. 1993. Relative survival of unmarked and fin-clipped coho salmon from Bear Lake, Alaska. The Progressive Fish-Culturist 55(3):141-148.

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-05, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds03-05.pdf

Weller, J. A., E. L. Jones III, and A. B. Holm. 2002. Production of coho salmon from the Unuk River, 2000-2001. Alaska Department of Fish and Game, Fishery Data Series 02-29, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds02-29.pdf

Weller, J. L., E. L. J. III, and A. B. Holm. 2006. Production of coho salmon from the Unuk River, 2003-2004. Alaska Department of Fish and Game, Fishery Data Series No. 06-60, Anchhorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-60.pdf

Weller, J. L., E. L. Jones III, D. R. Bernard, and A. B. Holm. 2003. Production of coho salmon from the Unuk River, 2001-2002. Alaska Department of Fish and Game, Fishery Data Series No. 03-27, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds03-27.pdf

Yanusz, R. J., S. A. McPherson, and D. R. Bernard. 1999. Production of coho salmon from the Taku River, 1997-1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-34, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-34.pdf

# APPENDIX A

Appendix A1.–Brood year, age classes and lengths of coho salmon by year sampled in the Nakwasina River, 2001–2006.

| | Brood year | 2004 | 2003 | 2003 | 2002 | 2002 | 2001 | 2002 | 2001 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sample year | | | 2006 | | | 2005 | | 2004 | |
| | Age class | 1.0 | 2.0 | 1.1 | 2.1 | 1.1 | 2.1 | 1.0 | 1.1 | 2.1 |
| Females | Sample size | - | - | 241 | 7 | 247 | 4 | - | 332 | 4 |
| | Percent | - | - | 97.2% | 2.8% | 98.4% | 1.6% | - | 98.8% | 1.2% |
| | SE | - | - | 1.1% | 1.1% | 0.8% | 0.8% | - | 0.6% | 0.6% |
| | Mean length | - | - | 650.0 | 663.6 | 638.7 | 672.5 | - | 639.6 | 615.0 |
| | SE | - | - | 2.3 | 20.3 | 2.2 | 24.4 | - | 2.2 | 26.8 |
| Males | Sample size | 15 | 1 | 388 | 5 | 373 | 10 | 20 | 488 | 7 |
| | Percent | 3.7% | 0.2% | 94.9% | 1.2% | 97.4% | 2.6% | 3.9% | 94.8% | 1.4% |
| | SE | 0.9% | 0.2% | 1.1% | 0.5% | 0.8% | 0.8% | 0.9% | 1.0% | 0.5% |
| | Mean length | 303.0 | 320.0 | 630.0 | 588.0 | 622.2 | 620.0 | 326.5 | 625.9 | 636.4 |
| | SE | 10.3 | - | 3.4 | 22.7 | 2.2 | 24.3 | 5.2 | 2.6 | 24.8 |
| All fish | Sample size | 15 | 1 | 629 | 12 | 620 | 14 | 20 | 820 | 11 |
| | Percent | 2.3% | 0.2% | 95.7% | 1.8% | 97.8% | 2.2% | 2.4% | 96.4% | 1.3% |
| | SE | 0.6% | 0.2% | 0.8% | 0.5% | 0.6% | 0.6% | 0.5% | 0.6% | 0.4% |
| | Mean length | 303.0 | 320.0 | 637.9 | 632.1 | 628.8 | 622.5 | 326.5 | 631.5 | 628.6 |
| | SE | 10.3 | - | 2.3 | 18.3 | 2.2 | 18.2 | 5.2 | 1.8 | 18.0 |

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Appendix A1.–page 2 of 2.

| | Brood year | 2001 | 2000 | 2000 | 1999 | 2000 | 1999 | 1998 | 1999 | 1998 | 1998 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sample year | | | 2003 | | | 2002 | | | | 2001 | |
| | Age class | 1.0 | 2.0 | 1.1 | 2.1 | 1.0 | 1.1 | 2.1 | 1.0 | 2.0 | 1.1 | 2.1 |
| Females | Sample size | - | - | 276 | 6 | - | 243 | 13 | - | - | 263 | 5 |
| | Percent | - | - | 97.9% | 2.1% | - | 94.9% | 5.1% | - | - | 98.1% | 1.9% |
| | SE | - | - | 0.9% | 0.9% | - | 1.4% | 1.4% | - | - | 0.8% | 0.8% |
| | Mean length | - | - | 634.5 | 640.0 | - | 625.8 | 646.5 | - | - | 629.9 | 658.0 |
| | SE | - | - | 2.1 | 17.7 | - | 2.7 | 10.6 | - | - | 2.3 | 18.3 |
| Males | Sample size | 16 | 5 | 405 | 7 | 2 | 409 | 12 | 4 | 2 | 433 | 14 |
| | Percent | 3.7% | 1.2% | 93.5% | 1.6% | 0.5% | 96.7% | 2.8% | 0.9% | 0.4% | 95.6% | 3.1% |
| | SE | 0.9% | 0.5% | 1.2% | 0.6% | 0.3% | 0.9% | 0.8% | 0.4% | 0.3% | 1.0% | 0.8% |
| | Mean length | 319.4 | 319.0 | 613.5 | 654.3 | 312.5 | 607.8 | 640.8 | 282.5 | 352.5 | 620.8 | 596.8 |
| | SE | 8.4 | 13.6 | 2.6 | 12.8 | 2.5 | 3.2 | 18.1 | 6.0 | 27.5 | 2.8 | 18.4 |
| All fish | Sample size | 16 | 5 | 681 | 13 | 2 | 652 | 25 | 4 | 2 | 696 | 19 |
| | Percent | 2.2% | 0.7% | 95.2% | 1.8% | 0.3% | 96.0% | 3.7% | 0.6% | 0.3% | 96.5% | 2.6% |
| | SE | 0.6% | 0.3% | 0.8% | 0.5% | 0.2% | 0.7% | 0.7% | 0.3% | 0.2% | 0.7% | 0.6% |
| | Mean length | 319.4 | 319.0 | 622.0 | 647.7 | 312.5 | 614.5 | 643.8 | 282.5 | 352.5 | 624.2 | 612.9 |
| | SE | 8.4 | 13.6 | 1.8 | 10.4 | 2.5 | 2.3 | 10.1 | 6.0 | 27.5 | 2.0 | 15.5 |

Appendix A2.–Recoveries of coded wire tags originating from Nakwasina River coho salmon in 2005 and 2006.

| | | | | | 2005 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Head | Tag code | Gear class | Date (CWT) | Stat week | Quadrant | District | Sub-district | Length | Survey site | Sample |
| | | | | | Random Recoveries | | | | | |
| 303662 | 40867 | TROLL | 9/3/2005 | 36 | NE | | | 525 | SITKA | 5031324 |
| 296851 | 40865 | TROLL | 7/9/2005 | 28 | NW | 113 | 31 | 562 | SITKA | 5030888 |
| 296305 | 40865 | TROLL | 7/5/2005 | 28 | NW | 113 | 41 | 578 | SITKA | 5030810 |
| 296339 | 40865 | TROLL | 7/6/2005 | 28 | NW | 113 | | 632 | SITKA | 5030828 |
| 296469 | 40867 | TROLL | 7/7/2005 | 28 | NW | 113 | 91 | 552 | SITKA | 5030855 |
| 295085 | 40867 | TROLL | 7/5/2005 | 28 | NW | | | 629 | HOONAH | 5119999 |
| 75714 | 40865 | TROLL | 7/10/2005 | 29 | NW | 113 | 91 | 612 | PELICAN | 5010038 |
| 295206 | 40865 | TROLL | 7/12/2005 | 29 | NW | | | 613 | HOONAH | 5110126 |
| 269303 | 40867 | TROLL | 7/12/2005 | 29 | NW | 113 | 61 | 602 | SITKA | 5030912 |
| 296577 | 40867 | TROLL | 7/12/2005 | 29 | NW | 113 | 31 | 611 | SITKA | 5030921 |
| 302879 | 40867 | TROLL | 7/15/2005 | 29 | NW | 113 | 21 | 635 | SITKA | 5030958 |
| 302389 | 40865 | TROLL | 7/20/2005 | 30 | NW | 113 | 31 | 620 | SITKA | 5031006 |
| 302444 | 40866 | TROLL | 7/22/2005 | 30 | NW | 113 | | 660 | SITKA | 5031016 |
| 302127 | 40865 | TROLL | 7/24/2005 | 31 | NW | 116 | 12 | 652 | SITKA | 5031031 |
| 93806 | 40867 | TROLL | 7/29/2005 | 31 | NW | 113 | | 600 | PELICAN | 5010086 |
| 303310 | 40865 | TROLL | 8/3/2005 | 32 | NW | 113 | 21 | 621 | SITKA | 5031099 |
| 295522 | 40866 | TROLL | 7/31/2005 | 32 | NW | | | 626 | HOONAH | 5110172 |
| 302182 | 40867 | TROLL | 8/1/2005 | 32 | NW | 113 | 62 | 642 | SITKA | 5031081 |
| 27460 | 40865 | TROLL | 8/8/2005 | 33 | NW | 114 | 21 | 580 | ELFIN COVE | 5020196 |
| 295633 | 40866 | TROLL | 8/10/2005 | 33 | NW | | | 674 | HOONAH | 5110206 |
| 295738 | 40865 | TROLL | 8/18/2005 | 34 | NW | 113 | 91 | 582 | HOONAH | 5110228 |
| 301299 | 40865 | TROLL | 8/17/2005 | 34 | NW | 113 | 41 | 606 | SITKA | 5031196 |
| 303414 | 40865 | TROLL | 8/19/2005 | 34 | NW | 113 | | 627 | SITKA | 5031232 |
| 288739 | 40865 | TROLL | 8/17/2005 | 34 | NW | 189 | 30 | 661 | YAKUTAT | 5140143 |
| 303499 | 40866 | TROLL | 8/20/2005 | 34 | NW | 113 | 31 | 664 | SITKA | 5031239 |
| 295815 | 40867 | TROLL | 8/19/2005 | 34 | NW | | | 568 | HOONAH | 5110234 |
| 303993 | 40865 | TROLL | 8/25/2005 | 35 | NW | 154 | | 615 | SITKA | 5031270 |
| 27520 | 40865 | TROLL | 8/26/2005 | 35 | NW | 114 | 21 | 620 | ELFIN COVE | 5020256 |
| 301419 | 40865 | TROLL | 8/26/2005 | 35 | NW | 113 | 45 | 685 | SITKA | 5031274 |
| 303505 | 40866 | TROLL | 8/22/2005 | 35 | NW | 113 | 35 | 574 | SITKA | 5031255 |
| 295844 | 40866 | TROLL | 8/21/2005 | 35 | NW | | | 634 | HOONAH | 5110252 |
| 303992 | 40867 | TROLL | 8/25/2005 | 35 | NW | 154 | | 579 | SITKA | 5031270 |
| 27539 | 40865 | TROLL | 8/29/2005 | 36 | NW | 114 | 21 | 615 | ELFIN COVE | 5020267 |
| 269064 | 40865 | TROLL | 8/30/2005 | 36 | NW | 113 | 45 | 631 | SITKA | 5031295 |
| 303561 | 40865 | TROLL | 8/29/2005 | 36 | NW | 113 | 31 | 633 | SITKA | 5031287 |
| 301478 | 40865 | TROLL | 8/28/2005 | 36 | NW | 113 | 61 | 645 | SITKA | 5031279 |
| 269097 | 40865 | TROLL | 9/9/2005 | 37 | NW | 113 | 62 | 635 | SITKA | 5031334 |
| 539584 | 40865 | TROLL | 9/6/2005 | 37 | NW | 113 | 91 | 650 | JUNEAU | 5040183 |
| 24035 | 40865 | TROLL | 9/9/2005 | 37 | NW | 189 | 30 | 663 | YAKUTAT | 5140220 |
| 539856 | 40865 | TROLL | 9/6/2005 | 37 | NW | 113 | 91 | 670 | JUNEAU | 5040183 |
| 27607 | 40865 | TROLL | 9/7/2005 | 37 | NW | 114 | 21 | | ELFIN COVE | 5020319 |
| 288913 | 40867 | TROLL | 9/10/2005 | 37 | NW | 189 | 30 | 662 | YAKUTAT | 5140225 |
| 288957 | 40865 | TROLL | 9/13/2005 | 38 | NW | 181 | 60 | 612 | YAKUTAT | 5140247 |
| 303705 | 40865 | TROLL | 9/11/2005 | 38 | NW | 113 | 31 | 645 | SITKA | 5031338 |
| 299185 | 40865 | TROLL | 9/15/2005 | 38 | NW | | | 668 | HOONAH | 5110329 |
| 299122 | 40865 | TROLL | 9/13/2005 | 38 | NW | 113 | 93 | 672 | HOONAH | 5110318 |
| 242055 | 40865 | TROLL | 9/16/2005 | 38 | NW | 113 | 91 | 672 | PELICAN | 5010218 |
| 276940 | 40865 | TROLL | 9/16/2005 | 38 | NW | 189 | 30 | 677 | YAKUTAT | 5140268 |
| 303764 | 40865 | TROLL | 9/13/2005 | 38 | NW | 113 | 45 | 749 | SITKA | 5031365 |
| 303762 | 40866 | TROLL | 9/13/2005 | 38 | NW | 113 | 45 | 635 | SITKA | 5031365 |
| 303749 | 40866 | TROLL | 9/13/2005 | 38 | NW | 113 | 41 | 670 | SITKA | 5031361 |
| 269123 | 40866 | TROLL | 9/13/2005 | 38 | NW | | | 676 | SITKA | 5031350 |
| 288915 | 40866 | TROLL | 9/11/2005 | 38 | NW | 189 | 30 | 745 | YAKUTAT | 5140229 |

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| Head | Tag code | Gear class | Date (CWT) | Stat week | Quadrant | District | Sub-district | Length | Survey site | Sample |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Random recoveries | | | | | |
| 230988 | 40867 | TROLL | 9/13/2005 | 38 | NW | 113 | 91 | 615 | PELICAN | 5010206 |
| 300806 | 40867 | TROLL | 9/16/2005 | 38 | NW | 113 | | 663 | SITKA | 5031372 |
| 299190 | 40867 | TROLL | 9/15/2005 | 38 | NW | | | 692 | HOONAH | 5110329 |
| 300849 | 40865 | TROLL | 9/19/2005 | 39 | NW | 113 | 45 | 598 | SITKA | 5031380 |
| 539899 | 40865 | TROLL | 9/20/2005 | 39 | NW | 113 | 97 | 637 | JUNEAU | 5040201 |
| 300852 | 40865 | TROLL | 9/19/2005 | 39 | NW | 113 | 45 | 645 | SITKA | 5031380 |
| 300887 | 40865 | TROLL | 9/20/2005 | 39 | NW | 113 | | 677 | SITKA | 5031387 |
| 300886 | 40865 | TROLL | 9/20/2005 | 39 | NW | 113 | | 683 | SITKA | 5031387 |
| 539822 | 40865 | TROLL | 9/22/2005 | 39 | NW | | | 708 | JUNEAU | 5040206 |
| 539208 | 40866 | TROLL | 9/23/2005 | 39 | NW | 113 | 91 | 590 | JUNEAU | 5040197 |
| 300888 | 40866 | TROLL | 9/20/2005 | 39 | NW | 113 | | 677 | SITKA | 5031387 |
| 299257 | 40866 | TROLL | 9/20/2005 | 39 | NW | | | 720 | HOONAH | 5110337 |
| 90753 | 40865 | PURSE | 8/17/2005 | 34 | NW | 113 | | 660 | EXCURSION INLET | 5100140 |
| 90752 | 40866 | PURSE | 8/17/2005 | 34 | NW | 113 | | 541 | EXCURSION INLET | 5100140 |
| 291238 | 40867 | TROLL | 8/30/2005 | 36 | SE | 105 | 10 | 578 | CRAIG | 5070330 |
| 303522 | 40867 | TROLL | 8/27/2005 | 35 | | | | 654 | SITKA | 5031280 |
| 259801 | 40867 | SPORT | 8/10/2005 | 33 | NW | 113 | 41 | 625 | SITKA | 5035507 |
| 81624 | 40865 | SPORT | 8/15/2005 | 34 | NW | 113 | 41 | 624 | SITKA | 5035543 |
| 81641 | 40866 | SPORT | 8/20/2005 | 34 | NW | 113 | 45 | 695 | SITKA | 5035562 |
| 81625 | 40867 | SPORT | 8/15/2005 | 34 | NW | 113 | 41 | 683 | SITKA | 5035544 |
| 259272 | 40865 | SPORT | 8/22/2005 | 35 | NW | 113 | 61 | 641 | SITKA | 5035596 |
| 81654 | 40865 | SPORT | 8/26/2005 | 35 | NW | 113 | 31 | 693 | SITKA | 5035577 |
| 305510 | 40865 | SPORT | 9/3/2005 | 36 | NW | 183 | 10 | 680 | YAKUTAT | 5145034 |
| 81671 | 40865 | SPORT | 9/2/2005 | 36 | NW | 113 | 45 | 688 | SITKA | 5035618 |
| 305509 | 40867 | SPORT | 9/3/2005 | 36 | NW | 183 | 10 | 710 | YAKUTAT | 5145033 |
| | | | | | Select recoveries | | | | | |
| 901837 | 40865 | TROLL | 9/10/2005 | 37 | NW | | | | SITKA | 5039972 |
| 259182 | 40867 | SPORT | 8/23/2005 | 35 | NW | 113 | 41 | | SITKA | 5035605 |

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| | | | | | | | | | 2006 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Head | Tag code | Gear class | Date (CWT) | Stat week | Quadrant | District | Sub-district | Length | Survey site | Sample |

| | | | | | Random recoveries | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 166535 | 41005 | TROLL | 7/21/2006 | 29 | NE | 109 | 61 | 445 | PORT ALEXANDER | 6080037 |
| 166829 | 41005 | TROLL | 8/3/2006 | 31 | NE | 109 | 10 | 520 | PORT ALEXANDER | 6080071 |
| 313809 | 41003 | TROLL | 7/12/2006 | 28 | NW | 113 | | 580 | SITKA | 6036661 |
| 313910 | 41003 | TROLL | 7/18/2006 | 29 | NW | 113 | 21 | 545 | SITKA | 6036709 |
| 27285 | 41003 | TROLL | 7/23/2006 | 30 | NW | 116 | | 590 | PELICAN | 6010077 |
| 299584 | 41003 | TROLL | 7/27/2006 | 30 | NW | 116 | 11 | 572 | HOONAH | 6110124 |
| 94443 | 41003 | TROLL | 7/31/2006 | 31 | NW | | | 430 | PELICAN | 6010092 |
| 94680 | 41003 | TROLL | 8/8/2006 | 32 | NW | | | 575 | PELICAN | 6010116 |
| 314310 | 41003 | TROLL | 8/9/2006 | 32 | NW | 113 | 41 | 625 | SITKA | 6036853 |
| 313914 | 41004 | TROLL | 7/18/2006 | 29 | NW | 113 | 45 | 570 | SITKA | 6036710 |
| 27745 | 41004 | TROLL | 7/21/2006 | 29 | NW | | | 580 | ELFIN COVE | 6020088 |
| 314534 | 41004 | TROLL | 8/3/2006 | 31 | NW | 116 | 11 | 540 | SITKA | 6036811 |
| 314540 | 41004 | TROLL | 8/4/2006 | 31 | NW | | | 575 | SITKA | 6036821 |
| 94650 | 41004 | TROLL | 8/8/2006 | 32 | NW | 113 | 91 | 570 | PELICAN | 6010109 |
| 299469 | 41005 | TROLL | 7/13/2006 | 28 | NW | 116 | 11 | 610 | HOONAH | 6110092 |
| 299612 | 41005 | TROLL | 7/28/2006 | 30 | NW | | | 581 | HOONAH | 6110132 |
| 299629 | 41005 | TROLL | 7/28/2006 | 30 | NW | | | 599 | HOONAH | 6110132 |
| 94523 | 41005 | TROLL | 7/31/2006 | 31 | NW | | | 545 | PELICAN | 6010097 |
| 94511 | 41005 | TROLL | 8/1/2006 | 31 | NW | 116 | 11 | 585 | PELICAN | 6010096 |
| 299735 | 41005 | TROLL | 8/5/2006 | 31 | NW | | | 610 | HOONAH | 6110174 |
| 314311 | 41005 | TROLL | 8/9/2006 | 32 | NW | 116 | 11 | 575 | SITKA | 6036854 |
| 166567 | 41005 | TROLL | 7/23/2006 | 30 | SE | 105 | 10 | 565 | PORT ALEXANDER | 6080043 |
| 278849 | 41003 | TROLL | 9/18/2006 | 38 | NE | 112 | | 585 | JUNEAU | 6046209 |
| 278850 | 41005 | TROLL | 9/18/2006 | 38 | NE | 112 | | 680 | JUNEAU | 6046209 |
| 305586 | 41003 | TROLL | 8/30/2006 | 35 | NW | 189 | 30 | 540 | YAKUTAT | 6140180 |
| 315188 | 41003 | TROLL | 9/5/2006 | 36 | NW | 113 | | 575 | SITKA | 6037044 |
| 321053 | 41003 | TROLL | 9/6/2006 | 36 | NW | 189 | 30 | 565 | YAKUTAT | 6140192 |
| 94946 | 41003 | TROLL | 9/8/2006 | 36 | NW | | | 640 | PELICAN | 6010168 |
| 95227 | 41003 | TROLL | 9/12/2006 | 37 | NW | | | 660 | PELICAN | 6010179 |
| 95272 | 41003 | TROLL | 9/13/2006 | 37 | NW | | | 700 | PELICAN | 6010182 |
| 315643 | 41003 | TROLL | 9/14/2006 | 37 | NW | 113 | | 525 | SITKA | 6037088 |
| 315645 | 41003 | TROLL | 9/15/2006 | 37 | NW | 113 | 62 | 650 | SITKA | 6037092 |
| 315649 | 41003 | TROLL | 9/15/2006 | 37 | NW | | | 605 | SITKA | 6037093 |
| 96425 | 41003 | TROLL | 9/16/2006 | 37 | NW | | | 656 | HOONAH | 6110331 |
| 95682 | 41003 | TROLL | 9/20/2006 | 38 | NW | | | 645 | PELICAN | 6010203 |
| 317161 | 41003 | TROLL | 9/21/2006 | 38 | NW | | | 655 | SITKA | 6037125 |
| 315055 | 41004 | TROLL | 8/23/2006 | 34 | NW | 113 | 45 | 540 | SITKA | 6036983 |
| 316980 | 41004 | TROLL | 8/31/2006 | 35 | NW | 113 | | 595 | SITKA | 6037014 |
| 94917 | 41004 | TROLL | 9/2/2006 | 35 | NW | | | 590 | PELICAN | 6010158 |
| 95621 | 41004 | TROLL | 9/16/2006 | 37 | NW | | | 630 | PELICAN | 6010188 |
| 95600 | 41004 | TROLL | 9/16/2006 | 37 | NW | | | 660 | PELICAN | 6010188 |
| 317115 | 41004 | TROLL | 9/17/2006 | 38 | NW | 113 | 45 | 625 | SITKA | 6037102 |
| 315039 | 41005 | TROLL | 8/22/2006 | 34 | NW | 113 | 45 | 460 | SITKA | 6036954 |
| 46789 | 41005 | TROLL | 8/22/2006 | 34 | NW | | | 590 | EXCURSION INLET | 6100067 |
| 315069 | 41005 | TROLL | 8/23/2006 | 34 | NW | 113 | 45 | 575 | SITKA | 6036985 |
| 315225 | 41005 | TROLL | 8/31/2006 | 35 | NW | 113 | 62 | 575 | SITKA | 6037016 |
| 94892 | 41005 | TROLL | 9/1/2006 | 35 | NW | | | 590 | PELICAN | 6010154 |
| 315173 | 41005 | TROLL | 9/5/2006 | 36 | NW | 113 | 91 | 520 | SITKA | 6037042 |
| 315198 | 41005 | TROLL | 9/6/2006 | 36 | NW | 113 | 41 | 570 | SITKA | 6037051 |
| 94997 | 41005 | TROLL | 9/12/2006 | 37 | NW | 113 | 91 | 655 | PELICAN | 6010177 |
| 95220 | 41005 | TROLL | 9/12/2006 | 37 | NW | 114 | 21 | 570 | PELICAN | 6010178 |
| 96275 | 41005 | TROLL | 9/12/2006 | 37 | NW | | | 619 | HOONAH | 6110307 |
| 96327 | 41005 | TROLL | 9/14/2006 | 37 | NW | 114 | 21 | 568 | HOONAH | 6110319 |
| 95298 | 41005 | TROLL | 9/14/2006 | 37 | NW | | | 585 | PELICAN | 6010185 |

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| Head | Tag code | Gear class | Date (CWT) | Stat week | Quadrant | District | Sub-district | Length | Survey site | Sample |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Random recoveries | | | | | |
| 96408 | 41005 | TROLL | 9/19/2006 | 38 | NW | 116 | 11 | 642 | HOONAH | 6110326 |
| 317148 | 41005 | TROLL | 9/20/2006 | 38 | NW | 113 | 41 | 655 | SITKA | 6037118 |
| 315257 | 41003 | TROLL | 9/5/2006 | 36 | | | | 590 | SITKA | 6037037 |
| 315260 | 41004 | TROLL | 9/5/2006 | 36 | | | | 630 | SITKA | 6037037 |
| 83328 | 41003 | SPORT | 7/24/2006 | 30 | NW | 113 | 41 | 585 | SITKA | 6035339 |
| 318031 | 41003 | SPORT | 7/25/2006 | 30 | NW | 113 | 41 | 631 | SITKA | 6035346 |
| 318374 | 41003 | SPORT | 8/4/2006 | 31 | NW | 113 | 61 | 590 | SITKA | 6035421 |
| 318067 | 41003 | SPORT | 8/22/2006 | 34 | NW | 113 | 45 | 612 | SITKA | 6035520 |
| 248047 | 41003 | SPORT | 8/25/2006 | 34 | NW | 113 | 61 | 650 | SITKA | 6035543 |
| 318085 | 41003 | SPORT | 9/22/2006 | 38 | NW | 113 | 43 | 635 | SITKA | 6035568 |
| 318367 | 41004 | SPORT | 7/28/2006 | 30 | NW | 113 | 45 | 625 | SITKA | 6035366 |
| 318476 | 41004 | SPORT | 7/29/2006 | 30 | NW | 113 | 41 | 580 | SITKA | 6035378 |
| 319130 | 41004 | SPORT | 7/29/2006 | 30 | NW | 113 | 41 | 630 | SITKA | 6035383 |
| 318352 | 41005 | SPORT | 7/15/2006 | 28 | NW | 113 | 61 | 540 | SITKA | 6035280 |
| 83338 | 41005 | SPORT | 7/31/2006 | 31 | NW | 113 | 45 | 600 | SITKA | 6035399 |
| 318379 | 41005 | SPORT | 8/5/2006 | 31 | NW | 113 | 61 | 540 | SITKA | 6035425 |
| 318493 | 41005 | SPORT | 8/13/2006 | 33 | NW | 113 | 71 | 650 | SITKA | 6035479 |
| 318073 | 41005 | SPORT | 8/24/2006 | 34 | NW | 113 | 41 | 645 | SITKA | 6035537 |
| 83364 | 41005 | SPORT | 8/25/2006 | 34 | NW | 113 | 61 | 620 | SITKA | 6035540 |
| 83367 | 41005 | SPORT | 8/26/2006 | 34 | NW | 113 | 45 | 565 | SITKA | 6035544 |
| 319137 | 41005 | SPORT | 9/1/2006 | 35 | NW | 113 | 62 | 615 | SITKA | 6035553 |
| 318084 | 41005 | SPORT | 9/22/2006 | 38 | NW | 113 | 43 | 660 | SITKA | 6035568 |
| | | | | | Select recoveries | | | | | |
| 900990 | 41004 | TROLL | 9/23/2006 | 38 | NW | 114 | 21 | | SITKA | 6039982 |
| 901116 | 41005 | TROLL | 9/11/2006 | 37 | NW | | | | SITKA | 6039976 |
| 318280 | 41003 | SPORT | 8/8/2006 | 32 | NW | 113 | 45 | | SITKA | 6035447 |
| 318278 | 41005 | SPORT | 8/7/2006 | 32 | NW | 113 | 45 | | SITKA | 6035442 |
| 288388 | 41005 | SPORT | 9/12/2006 | 37 | NW | 113 | 41 | | SITKA | 6035567 |

Appendix A3.–Capture and recovery data from the Nakwasina River coho salmon mark–recapture study, 2005 and 2006, by section and date.

| Week# | Section | Original captures | Recaptures | Total captures | Proportion (Floy™) tagged | Original captures | Recaptures | Total captures | Proportion (Floy™) tagged |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2005 | | | | 2006 | |
| 35 | 2 | | | | | 1 | | 1 | 0.00 |
| 36 | 2 | | | | | 7 | | 7 | 0.00 |
| 37 | 2 | 4 | | 4 | 0.00 | 16 | | 16 | 0.00 |
| | 3 | | | | | 2 | | 2 | 0.00 |
| 38 | 2 | 1 | | 1 | 0.00 | 8 | | 8 | 0.00 |
| | 3 | | | | | 1 | | 1 | 0.00 |
| | TW | | | | | 9 | | 9 | 0.00 |
| 39 | 2 | 6 | | 6 | 0.00 | 12 | | 12 | 0.00 |
| | 3 | | | | | 1 | | 1 | 0.00 |
| | TW | 4 | | 4 | 0.00 | 6 | | 6 | 0.00 |
| 40 | 2 | 30 | | 30 | 0.00 | 27 | | 27 | 0.00 |
| | 3 | | | | | 39 | | 39 | 0.00 |
| | TW | 9 | | 9 | 0.00 | | | | |
| 41 | 1 | | | | | 9 | 1 | 10 | 0.10 |
| | 2 | 20 | 2 | 22 | 0.09 | 6 | 1 | 7 | 0.14 |
| | 3 | 32 | 1 | 33 | 0.03 | 81 | 6 | 87 | 0.07 |
| 42 | 1 | | | | | 22 | 4 | 26 | 0.15 |
| | 2 | 32 | | 32 | 0.00 | 53 | | 53 | 0.00 |
| | 3 | 20 | 2 | 22 | 0.09 | 165 | 6 | 171 | 0.04 |
| | TW | | | | | 22 | | 22 | 0.00 |
| 43 | 1 | | | | | 5 | | 5 | 0.00 |
| | 2 | 74 | 7 | 81 | 0.09 | 40 | 6 | 46 | 0.13 |
| | 3 | 51 | 2 | 53 | 0.04 | 132 | 8 | 140 | 0.06 |
| | TW | | | | | 3 | | 3 | 0.00 |
| 44 | 1 | 8 | 1 | 9 | 0.11 | 26 | 9 | 35 | 0.26 |
| | 2 | 85 | 18 | 103 | 0.17 | 38 | 12 | 50 | 0.24 |
| | 3 | 37 | 4 | 41 | 0.10 | 131 | 13 | 144 | 0.09 |
| 45 | 1 | | | | | 16 | 6 | 22 | 0.27 |
| | 2 | 105 | 14 | 119 | 0.12 | 107 | 54 | 161 | 0.34 |
| | 3 | 9 | 1 | 10 | 0.10 | 70 | 9 | 79 | 0.11 |
| | TW | 3 | | 3 | 0.00 | | | 0 | |
| 46 | 1 | 60 | 15 | 75 | 0.20 | | | 0 | |
| | 2 | 63 | 7 | 70 | 0.10 | 105 | 51 | 156 | 0.33 |
| | 3 | 26 | 2 | 28 | 0.07 | 56 | 7 | 63 | 0.11 |
| 47 | 1 | 25 | 16 | 41 | 0.39 | | | 0 | |
| | 2 | 95 | 32 | 127 | 0.25 | 75 | 62 | 137 | 0.45 |
| | 3 | 35 | 3 | 38 | 0.08 | 125 | 42 | 167 | 0.25 |
| 48 | 2 | | | | | 109 | 108 | 217 | 0.50 |
| 49 | 1 | 29 | 10 | 39 | 0.26 | 60 | 34 | 94 | 0.36 |
| | 2 | | | | | 33 | 48 | 81 | 0.59 |
| | 3 | 12 | 3 | 15 | 0.20 | | | 0 | |
| 50 | 1 | 34 | 11 | 45 | 0.24 | 13 | 17 | 30 | 0.57 |
| | 2 | 6 | 1 | 7 | 0.14 | 2 | | 2 | 0.00 |
| | 3 | 5 | 1 | 6 | 0.17 | 1 | 1 | 2 | 0.50 |
| Total | | 920 | 153 | 1,073 | 0.14 | 1,634 | 505 | 2,139 | 0.24 |

Appendix A4.–Predicting escapement from index counts using an expansion factor.

The expansion factor provides a means of predicting escapement in years where only an index count of the escapement is available, i.e. no weir counts or mark–recapture experiments were conducted. The expansion factor is the average over several years of the ratio of the escapement estimate (or weir count) to the index count.

Systems where escapement is known

On systems where escapement can be completely enumerated with weirs or other complete counting methods, the expansion factor is an estimate of the expected value of the "population" of annual expansion factors ($\pi$'s) for that system:

$$\bar{\pi} = \frac{\sum_{y=1}^{k} \pi_y}{k} \tag{1}$$

where $\pi_y = N_y / C_y$ is the observed expansion factor in year $y$, $N_y$ is the known escapement in year $y$, $C_y$ is the index count in year $y$, and $k$ is the number of years for which these data are available to calculate an annual expansion factor.

The estimated variance for expansion of index counts needs to reflect two sources of uncertainty for any predicted value of $\pi$, ($\pi_p$). First is an estimate of the process error ($var(\pi)$; the variation across years in the $\pi$'s, reflecting, for example, weather or observer-induced effects on how many fish are counted in a survey for a given escapement. Second is the sampling variance of $\bar{\pi}$ ($var(\bar{\pi})$), which will decline as we collect more data pairs.

The variance for prediction will be estimated (Neter et al. 1990):

$$v\hat{a}r(\pi_p) = v\hat{a}r(\pi) + v\hat{a}r(\bar{\pi}) \tag{2}$$

where:

$$v\hat{a}r(\pi) = \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k-1} \tag{3}$$

and:

$$v\hat{a}r(\bar{\pi}) = \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k(k-1)} \tag{4}$$

such that:

$$v\hat{a}r(\pi_p) = \frac{\sum_{y=1}^{k} (\pi_y - \bar{\pi})^2}{k-1} + \frac{\sum_{y=1}^{q} (\pi_y - \bar{\pi})^2}{k(k-1)} \tag{5}$$

-continued-

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## Systems where escapement is estimated

On systems where escapement is estimated, the expansion factor is an estimate of the expected value of the "population" of annual expansion factors ($\pi$'s) for that system:

$$\overline{\pi} = \frac{\sum_{y=1}^{k} \hat{\pi}_y}{k} \tag{6}$$

where $\hat{\pi}_y = \hat{N}_y / C_y$ is the estimate of the expansion factor in year $y$, $\hat{N}_y$ is the estimated escapement in year $y$, and other terms are as described above.

The variance for prediction will again be estimated:

$$v\hat{a}r(\pi_p) = v\hat{a}r(\pi) + v\hat{a}r(\overline{\pi}) \tag{7}$$

The estimate of $var(\pi)$ should again reflect only process error. Variation in $\hat{\pi}$ across years, however, represents process error plus measurement error within years (e.g. the mark–recapture induced error in escapement estimation) and is described by the relationship (Mood et al. 1974):

$$V(\hat{\pi}) = V[E(\hat{\pi})] + E[V(\hat{\pi})] \tag{8}$$

This relationship can be rearranged to isolate process error, that is:

$$V[E(\hat{\pi})] = V[\hat{\pi}] - E[V(\hat{\pi})] \tag{9}$$

An estimate of $var(\pi)$ representing only process error therefore is:

$$v\hat{a}r(\pi) = v\hat{a}r(\hat{\pi}) - \frac{\sum_{y=1}^{k} v\hat{a}r(\hat{\pi}_y)}{k} \tag{10}$$

where $v\hat{a}r(\hat{\pi}_y) = v\hat{a}r(\hat{N}_y)/C_y^2$ and $v\hat{a}r(\hat{N}_y)$ is obtained during the experiment when $N_y$ is estimated. We can calculate:

$$v\hat{a}r(\hat{\pi}) = \frac{\sum_{y=1}^{k}(\hat{\pi}_y - \overline{\pi})^2}{k-1} \tag{11}$$

and we can estimate $var(\overline{\pi})$ similarly to as we did above:

$$v\hat{a}r(\overline{\pi}) = \frac{\sum_{y=1}^{k}(\hat{\pi}_y - \overline{\pi})^2}{k(k-1)} \tag{12}$$

where both process and measurement errors need to be included.

For large $k$ ($k > 30$), equations (11) and (12) provide reasonable parameter estimates, however for small $k$ the estimates are imprecise and may result in negative estimates of variance when the results are applied as in equation (7).

Because $k$ is typically $< 10$, we will estimate $var(\hat{\pi})$ and $var(\overline{\pi})$ using parametric bootstrap techniques (Efron and Tibshirani 1993). The sampling distributions for each of the $\hat{\pi}_y$ are modeled using Normal distributions with means $\hat{\pi}_y$ and variances $v\hat{a}r(\hat{\pi}_y)$. At each bootstrap iteration, a bootstrap value $\hat{\pi}_{y(b)}$ is drawn from each of these Normal distributions and the bootstrap value $\hat{\pi}_{(b)}$ is randomly chosen from the $k$ values of $\hat{\pi}_{y(b)}$. Then, a bootstrap sample of size $k$ is drawn from the $k$ values of $\hat{\pi}_{y(b)}$ by sampling with replacement, and the mean of this bootstrap is the bootstrap value $\overline{\pi}_{(b)}$. This procedure is repeated $B = 1,000,000$ times. We can then estimate $var(\hat{\pi})$ using:

$$v\hat{a}r_B(\hat{\pi}) = \frac{\sum_{b=1}^{B}(\hat{\pi}_{(b)} - \overline{\hat{\pi}_{(b)}})^2}{B-1} \tag{13}$$

where:

$$\overline{\hat{\pi}_{(b)}} = \frac{\sum_{b=1}^{B}\hat{\pi}_{(b)}}{B} \tag{14}$$

and we can calculate $var_B(\overline{\pi})$ using equations (13) and (14) with appropriate substitutions. The variance for prediction is then estimated:

$$v\hat{a}r(\pi_p) = v\hat{a}r_B(\hat{\pi}) - \frac{\sum_{y=1}^{k}v\hat{a}r(\hat{\pi}_y)}{k} + v\hat{a}r_B(\overline{\pi}) \tag{15}$$

As the true sampling distributions for the $\hat{\pi}_y$ are typically skewed right, using a Normal distribution to approximate these distributions in the bootstrap process will result in estimates of $var(\hat{\pi})$ and $var(\overline{\pi})$ that are biased slightly high, but simulation studies using values similar to those realized for this application indicated that the bias in equation (15) is $< 1\%$.

Predicting Escapement

In years when an index count ($C_p$) is available but escapement ($N_p$) is not known, it can be predicted:

$$\hat{N}_p = \overline{\pi}\, C_p \tag{16}$$

and:

$$v\hat{a}r(\hat{N}_p) = C_p^2 v\hat{a}r(\pi_p) \tag{17}$$

Appendix A5.–Data files used to estimate parameters of the Nakwasina River coho population, 2004 through 2006.

| Data file[a] | Description |
|---|---|
| 2005-2006_Adult_CWT_Recoveries.xls | Recovery information from 2005–2006 coded wire tag recoveries in Southeast Alaska. |
| Nakwasina_River_2005-2006_M-R_and_CWT.xls | Mark, recapture, and coded wire tag recovery information from fish captured in Nakwasina River in 2005 and 2006. |
| 2005-2006AdultAWL.xls | Age and length Information including summary statistics of adult coho captured in Nakwasina River in 2005–2006. |
| 2004-2005_smolt_AWL_data.xls | 2004 and 2005 smolt raw data including summaries of analyzed data. |

[a]  Data files were archived at and are available from the Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.